IMPACT OF RESERVOIR EVAPORATION AND EVAPORATION SUPPRESSION ON WATER SUPPLY CAPABILITIES

A Thesis

by

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ABSTRACT

Reservoir storage is essential for developing dependable water supplies and is a major component of the river system water budget. The storage contents of reservoirs fluctuate greatly with variations in water use and climatic conditions that range from severe multiple-year droughts to floods. Water surface evaporation typically represents a major component of the reservoir water budget. This thesis investigates the effects of evaporation and potential reductions in this evaporation on the water supply capabilities of reservoirs in Texas.

As part of this research, a literature review based assessment of capabilities for reducing reservoir evaporation using monolayer films and other methods was performed. The literature review assessment provides an overview of past evaporation suppression studies performed using monolayer films and other evaporation suppression technologies including water shades and covers. The overview provides a summary on monolayer film application techniques, environmental impacts, operational and material costs, evaluation methods, and achievable evaporation reduction rates.

This research project quantifies the impact of reservoir evaporation on water supply availability/reliability by using the Texas Water Availability Modeling (WAM) System which consists of the Water Rights Analysis Package (WRAP) and 21 sets of WRAP input files covering the 23 river basins of the state, a geographic information system (GIS), and contains over 8,000 water rights permits, which include 3,435 reservoirs. The impact of evaporation on water supply availability/reliability was

evaluated by performing several analyses in which evaporation rates are reduced by specified percentages starting when storage levels drop below certain trigger percentages of reservoir storage capacity.

DEDICATION

To all those who have supported me through the course of my graduate studies.

ACKNOWLEDGEMENTS

I would like to thank Dr. Ralph Wurbs, my advising professor and advisory committee chair. He was always willing to lend a helping hand throughout the completion of this research. Without his guidance, support, and patience it would have been difficult to complete this thesis. I would also like to thank Dr. Munster and Dr. Cahill for agreeing to serve on my committee.

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NOMENCLATURE

ALU	Single Layered Aluminized Net
BLPE	Single Layered Blue Net
BPE	Single Layered Black Net
CELR	Chemical Engineering Laboratory Report
CWC	Government of India, Central Water Commission
EPDM	Ethylene Propylene Diene Monomer
ET	Evapotranspiration
GIS	Geographic Information Systems
GPE	Single Layered Blue Net
NRM	Queensland Government Department of Natural Resources and Mines
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WAM	Water Availability Modeling
WPE	Single Layered White Net
WRAP	Water Availability Modeling
2BPE	Double Layered Black Net
2WPE	Double Layered White Net

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CHAPTER I

INTRODUCTION

1.1 Problem Statement

Population growth and depleting groundwater reserves are resulting in intensifying demands on surface water resources used to supply agricultural, municipal, industrial, environmental, and other water needs of Texas. Reservoir storage is essential for developing dependable water supplies and serves as a major component of the river/reservoir system water budget which significantly affects water supply reliabilities. Reservoir evaporation suppression technologies, particularly monolayer films, have been investigated for many years and are now receiving increasingly more attention as demands on limited water supplies intensify. This research quantifies the impacts of reservoir evaporation losses on water supply reliabilities by using the Texas Commission on Environmental Quality (TCEQ) Water Availability Modeling (WAM) System. In addition, the effect of reservoir evaporation reductions on water supply capabilities is evaluated.

Because Texas is one of the fastest growing states in the nation, it is important to maintain and provide reliable water supplies. In the last 10 years population has increased 12.7%, nearly twice that of the nation, 6.4% (TWDB 2007). According to the Texas Data Center and the Office of the State Demographer this rapid increase in population will continue with a projected 82% increase from the year 2010 to 2060

(TWDB 2012). By performing evaporation suppression water supply availability/reliability studies, additional reservoir water volumes for future populations can be quantified. In addition to a rapidly increasing population, Texas has a very diverse geography reflected in 10 climatic regions, 14 soil regions, and 11 ecological regions. Varying climatic conditions affect water supply reservoirs differently across the state and play an important role in surface evaporation loss. By performing evaporation suppression studies across the state, the impact of climatic conditions is determined. In evaluating water supply availability/reliability it is important to consider major water impoundments across the state. Texas has 3,450 reservoirs with water right permits, including 196 major reservoirs defined as impoundments with at least 5,000 acre-feet of storage capacity at normal operating levels (TWDB 2007).

As a result of having reservoirs with large surface areas, a large amount of water is available for evaporation. Therefore evaporation from reservoir water surfaces accounts for a significant portion of the stream flow stored to develop dependable water supplies statewide. Since climate and evaporation rates differ across the state, evaporation suppression effects vary greatly between the different regions of the state. Although reservoir evaporation suppression measures have not been implemented to a significant extent in the past, such measures could possibly be a significant water conservation strategy in the future. The TCEQ WAM System provides capabilities to quantify the effects of evaporation and evaporation suppression on water availability and supply reliability.

1.2 Objectives of Research

The objectives of the research are:

1. to quantify the impact of evaporation from reservoir water surfaces on water supply capabilities in Texas using the TCEQ WAM System
2. to develop a literature review based assessment of capabilities for reducing reservoir evaporation using monolayer films and other methods
3. to investigate the potential improvements in water supply capabilities that could be achieved using monolayer films or other evaporation suppression methods.

The TCEQ WAM System will be used to develop river/reservoir system water budgets and determine water supply reliabilities with and without evaporation suppression. A statewide investigation will be combined with more detailed studies of several selected reservoir/river systems. A literature review of evaporation suppression technologies focused primarily but not exclusively on monolayer films will provide a basis for assessing the characteristics and range of possible evaporation reduction levels.

1.3 Texas Water Availability Modeling (WAM) System

Senate Bill 1, enacted by the Texas Legislature in 1997, authorized the WAM system to be developed under the leadership of the TCEQ (Wurbs 2005). The WAM system was developed to provide capabilities for assessing water availability and reliability following the prior appropriation doctrine of the State of Texas. The water availability modeling system was implemented during the years of 1997-2003 and provides a consistent set of databases and modeling tools for use both in planning studies and in preparing and evaluating water rights permits applications (Wurbs 2011a).

The Texas WAM system includes 21 sets of WRAP input files covering the 23 river basins of the state , 8,000 water rights permits, which include 3,435 reservoirs, a geographic information system (GIS), and other supporting databases (Wurbs 2011a). Figure 1.1 shows a river basin breakdown of the TCEQ WAM datasets.

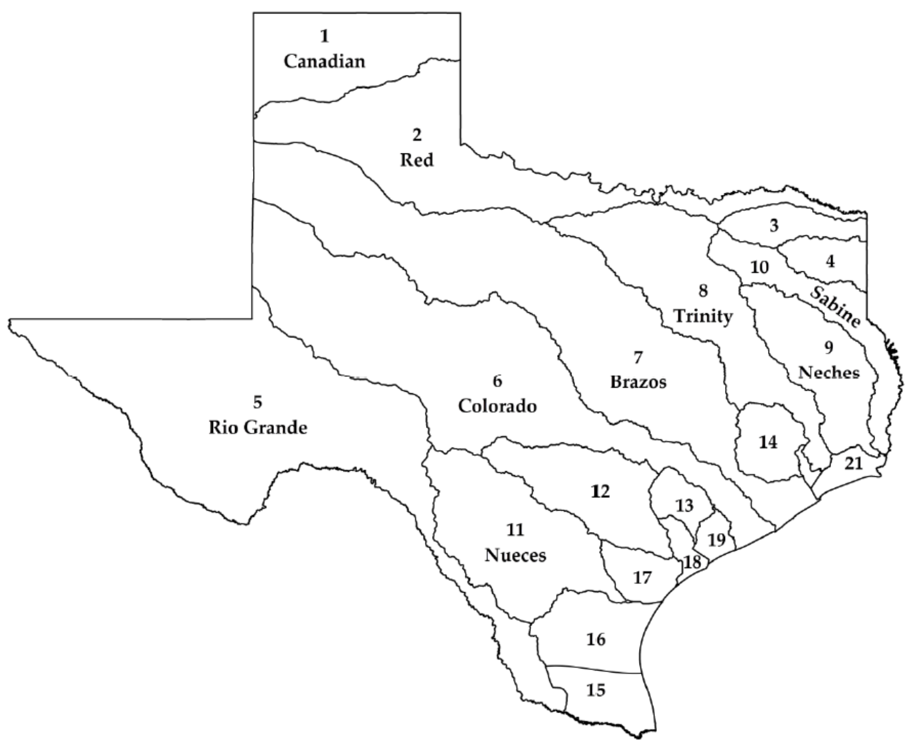

Figure 1.1 WAM System 21 River Basins (Wurbs 2011a)

Standard input datasets for each basin contain a file with water management information and hydrology files. Hydrology files input data include monthly naturalized streamflow volumes at gauged sites, watershed parameters for distributing naturalized flows from gaged to ungagged sites, and net reservoir evaporation rates at primary control points (Wurbs 2011b). The TCEQ WAM system has two sets of input files for each of the river basins, full authorized and current use. The full authorized use input dataset is based on the following premises.

1. Water use targets are the full amounts authorized by the permits.
2. Full reuse with no return flow is assumed.
3. Reservoir storage capacities are those specified in the permits, which typically reflect no sediment accumulation.
4. Term permits are not included (Wurbs 2011a).

The Current Use input dataset is based on the following premises.

1. The water use target for each right is based on the maximum annual amount used in any year during a recent ten year period.
2. Best estimates of actual return flows are adopted.
3. Reservoir storage capacities and elevation-area-volume relations for major reservoirs reflect year 2000 conditions of sedimentation.
4. Term permits are included (Wurbs 2011a).

Table 1.1 lists the period of record, number of primary and total control points, number of water right (WR) and instream flow (IF) records, and the number of reservoirs for each of the 21 WAM river basins.

Table 1.1 Texas WAM System Model Datasets

Map ID	Major River Basin or Coastal Basin	Period of Analysis	Number of Primary Control Points	Number of Total Control Points	Number of WR Record Rights	Number of IF Record Rights	Number of Model Reser-voirs	Reservoir Storage Capacity (acre-feet)	WAM File Name
				Major River Basins					
1	Canadian River Basin	1948-98	12	85	56	0	47	966,000	CRUN3
2	Red River Basin	1948-98	47	447	494	101	245	4,124,000	red3
3	Sulphur River Basin	1940-96	8	83	85	10	57	753,000	sulphur3
4	Cypress Bayou Basin	1948-98	10	147	163	1	91	902,000	cyp3
5	Rio Grande Basin	1940-00	55	957	2,584	4	113	23,918,000	RG3
6	Colorado River Basin and Brazos-Colorado Coastal	1940-98	45	2,395	1,922	86	511	4,763,000	C3
7	Brazos River Basin and San Jacinto-Brazos Coastal	1940-97	77	3,842	1,634	122	678	4,695,000	Bwam3
8	Trinity River Basin	1940-96	40	1,343	1,027	35	700	7,504,000	Trin3
9	Neches River Basin	1940-96	20	306	328	19	180	3,904,000	Neches3
10	Sabine River Basin	1940-98	27	376	310	21	207	6,401,000	Sabine3
11	Nueces River Basin	1934-96	41	542	373	30	121	1,040,000	N_RUN3
12	Guadalupe San Antonio River	1934-89	46	1,338	848	200	238	808,000	gsa_run3
13	Lavaca River Basin	1940-96	7	185	72	30	22	235,000	lav3
14	San Jacinto River Basin	1940-96	17	412	150	15	114	637,000	sjarun3
				Coastal Basin					
15	Lower Nueces-Rio Grande	1948-98	16	119	70	6	42	101,700	LowerNrg3
16	Upper Nueces-Rio Grande	1948-98	13	81	34	2	22	11,000	UpperNRG3
17	San Antonio-Nueces	1948-98	9	53	12	2	9	1,480	SAN_R3
18	Lavaca-Guadalupe Coastal	1940-96	2	68	10	0	0	0	lavgua3
19	Colorado-Lavaca Coastal	1940-96	1	111	27	4	8	7,230	col-lav3
20	Trinity-San Jacinto Coastal	1940-96	2	94	24	0	13	4,880	TSJ3
21	Neches-Trinity Coastal	1940-96	4	245	138	9	31	58,000	NT3
	Total		499	13,229	10,361	697	3,449	60,834,290	

1.4 Water Rights Analysis Package

The Water Rights Analysis Package (WRAP), developed at Texas A&M University under the direction of Dr. Ralph Wurbs, is a generalized river and reservoir model that is designed to simulate the management of water resources of a river basin or multiple-basins under a priority-based water allocation system (Wurbs 2005). The model has numerous assessment capabilities such as hydrologic and institutional water availability and reliability for water supply diversions, environmental instream flows, hydroelectric energy generation, and reservoir storages (Wurbs 2011c).

The WRAP model is a set of computer programs consisting of *WinWRAP*, WRAP-SIM, WRAP-TABLES, and WRAP-HYD. *WinWRAP* is a user interface for applying the WRAP modeling system on personal computers with the Microsoft Windows operating system (Wurbs 2011b). WRAP-SIM is the program used to simulate the management of water resources of a particular river basin study area using a priority order system (Wurbs 2011b). WRAP-TABLES is the post-processor program used to organize, summarize, and display simulation results (Wurbs 2011b). WRAP-HYD assists in developing stream flow and reservoir net evaporation-precipitation depth data for the SIM hydrology input files (Wurbs 2011a).

A WRAP simulation study involves assessing capabilities for meeting specified water management and use requirements during a hypothetical repetition of historical hydrology. The overall modeling process includes the following tasks.

1. Sequences of monthly naturalized streamflows for a specified period-of-analysis are developed at predetermined gauging stations (Wurbs 2011c).
2. Monthly naturalized streamflows are extended and distributed to all pertinent ungauged locations (Wurbs 2011c).
3. The rights/reservoir/river system water allocation/management/use system is simulated (Wurbs 2011c).
4. Simulation results are organized and water supply reliability indices, flow and storage frequency relationships, and other summary statistics are computed (Wurbs 2011c).

There are many results that are produced from running a WRAP simulation. Outputs of a simulation typically include:

- naturalized, regulated, and unappropriated flows for each control point,
- return flows from diversions that are returned at each control point,
- diversions, diversion shortages, and return flows for each water right,
- instream flow targets and shortages,
- storage and net evaporation-precipitation for each reservoir, right, and control point
- amount of water available and stream flow depletions for each right.

Results are presented as computed reliability indices, including volume and period reliabilities, stream flow and storage frequency relationships which are organized in tables (Wurbs 2011a). Volume reliability is a ratio of the water volume supplied to the demand target to the volume target (Wurbs 2005). Period reliability is the number of periods the target demand is either fully supplied or a specified percentage of the target is equaled or exceeded (Wurbs 2011a).

1.5 WRAP-SIME and TWDB Evaporation and Precipitation Datasets

The WAM System provides capabilities for determining net evaporation-precipitation volumes for each reservoir in the model for each month of a 50 to 60 year hydrologic period-of-analysis for specified scenarios. The WAM System input datasets for each river basin include a file of monthly net evaporation less precipitation depths in feet. However, simulation of evaporation volumes, exclusive of precipitation, required modifications to both the WRAP-SIM simulation model and the WAM input datasets.

A version of the WRAP-SIM simulation model called SIME was developed by Dr. Ralph Wurbs specifically for this research that directly reads separate datasets of monthly evaporation depths and monthly precipitation depths from a statewide database maintained by the Texas Water Development Board (TWDB). The SIME version of the WRAP-SIM program was written to allow for evaporation rate reductions to be specified and enable the calculation of evaporation volumes exclusive of precipitation. WRAP-SIME computes the mean annual net reservoir surface evaporation-precipitation volume, evaporation volume, and precipitation volume at the end of each analysis. Additional input data regarding monthly and annual precipitation and lake evaporation is required for reservoirs in the dataset. Further discussion concerning WRAP-SIME is provided in Chapter IV.

Precipitation gages and evaporation pans have been maintained at many sites throughout Texas by many federal, state, and local agencies and individuals since the early 1900's. The periods-of-record of the observed data vary between sites. There are many more precipitation gages than evaporation pans. The Texas Water Development Board (TWDB) has compiled the available historical precipitation and pan evaporation data and developed monthly rates for the entire state by one-degree quadrangles of latitude and longitude for the period since 1940. The TWDB maintains these monthly evaporation and precipitation datasets at http://midgewater.twdb.state.tx.us/Evaporation/evap.html.

The monthly precipitation and evaporation depths for the 92 one-degree quadrangles covering Texas as shown in Figure 1.2 date back to 1940 and are updated each year to add data for the preceding year. The TWDB datasets have been used in the past, along with other data in some cases, to develop the net evaporation less precipitation rates included in the TCEQ WAM System. The separate datasets for evaporation rates and precipitation rates are used in the simulation studies presented in this thesis.

A total of 168 one-degree quadrangles covering an area extending 12 degrees longitude and 14 degrees latitude encompass adjacent surrounding land area along with

Texas. Complete monthly precipitation and evaporation data for 1940 to near the present are available for the 92 one-degree quadrangles shown in Figure 1.1 that encompass the state. The datasets include an additional 76 quadrangles located outside of Texas, but there are periods of missing data for these quadrangles. The 168 one-degree quadrangles define a grid with 12 rows and 14 columns. Although areas vary a little between quadrangles, each quadrangle encompasses about 4,000 square miles.

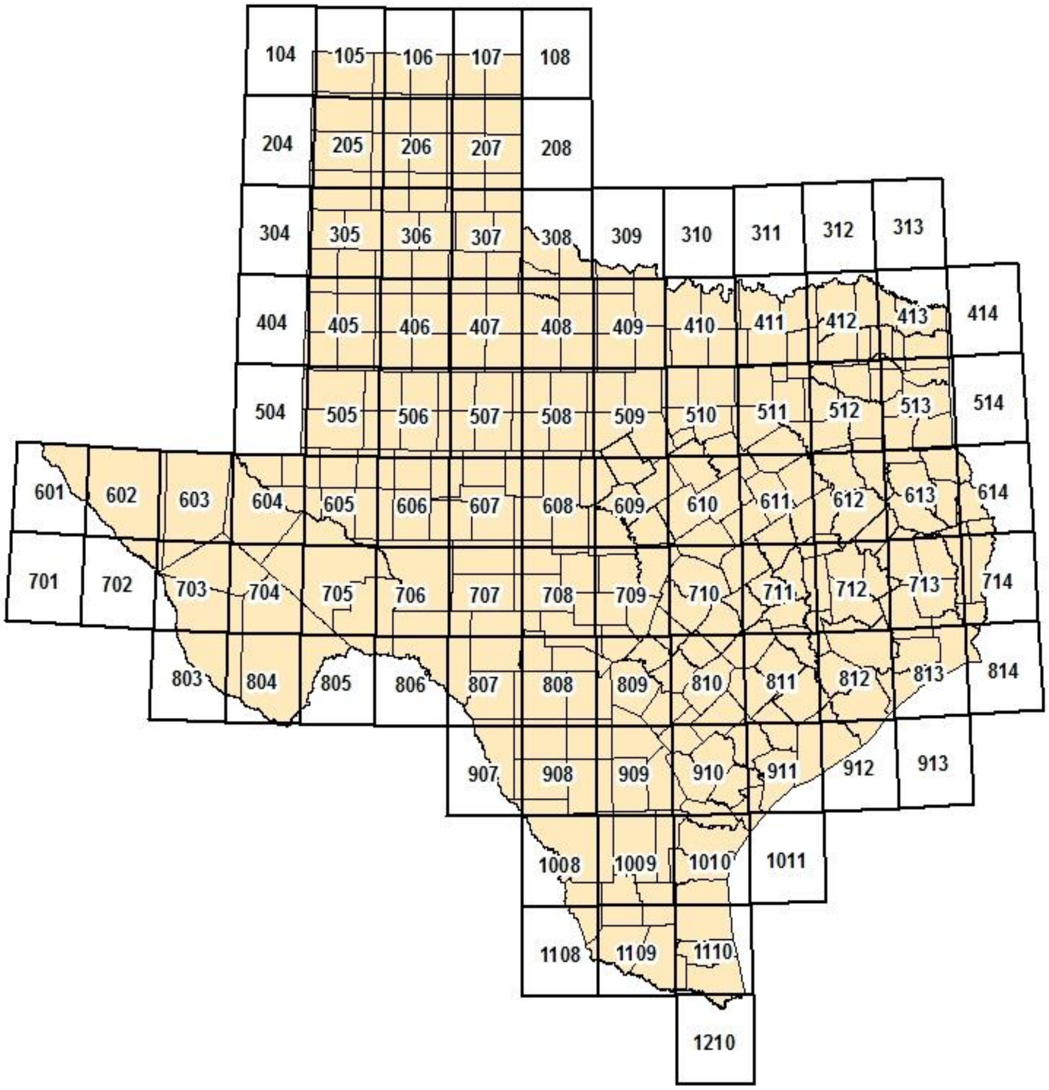

Figure 1. 2 Quadrangle Map for TWDB Evaporation and Precipitation Datasets (TWDB n.d.)

CHAPTER II

LITERATURE REVIEW OF RESERVOIR EVAPORATION AND EVAPORATION SUPPRESSION

The literature review will provide an overview of evaporation, evaporation suppression technologies using monolayer films, other evaporation suppression technologies, and techniques used to determine reservoir surface evaporation. Past evaporation suppression field studies provide a basis for assessing capabilities for reducing reservoir evaporation using evaporation suppression techniques. A majority of the discussion will center on the use of monolayer films as evaporation suppressants.

2.1 Evaporation

Evaporation is a key process in the hydrologic cycle. It is the primary pathway through which water moves from the liquid stage back into the water cycle as atmospheric water vapor (USGS 2011). Studies have shown that oceans, seas, lakes, and rivers provide nearly 80 percent of the moisture in the atmosphere via evaporation, with the remaining 20 percent being contributed by plant transpiration (USGS 2011). Evaporation is an important process because it is the primary mechanism supporting the surface-to-atmosphere portion of the water cycle.

Evaporation of a substance occurs when there is enough kinetic energy for a water molecule to vaporize into a gas. There are several factors which affect how quickly a water molecule changes from liquid to gas. The six most important factors that affect evaporation are (CWC 2006):

- wind velocity – as evaporation takes place, the water vapor gathers above the water's surface. If there is wind moving over the reservoir surface, the concentration of water vapor is kept low, encouraging a faster evaporation rate.
- temperature – evaporation is directly related to kinetic energy. As temperature increase, water molecules begin to move faster which increases the kinetic energy therefore increasing evaporation rates.
- surface area – as a result of a larger surface area, more water molecules are exposed to the air. The enlarged surface area allows for more heat and wind contact between more molecules at any one time. This therefore leads to increased evaporation rates.
- humidity – is used as a term to define the amount of water vapor in the air. When humidity is high, there is a large amount of water vapor in the air making it difficult to receive any from evaporation. Hence when there is high humidity, the rate of evaporation tends to be lower.
- vapor pressure – pressure is described as the force per unit area applied in a direction perpendicular to the surface of an object. If there is less force exerted on the evaporating surface, the molecules will be able to more easily escape into the air thus leading to increased evaporation rates.

- molecular forces – are described as the forces of attraction or repulsion which act between neighboring particles: atoms, molecules, or ions. Therefore the stronger the molecular forces the lower the evaporation rate.

2.2 Evaporation Suppression

The idea of evaporation suppression dates back many years. Benjamin Franklin is credited with being the first to discover that an oily substance would retard evaporation when placed on water surfaces (La Mar and Healy 1965). During the early 1900s it was discovered that the substances used to retard evaporation were formed from polar molecules consisting of a hydrophobic (water-repelling) and hydrophilic (water-attacking) part (Frenkiel 1956). The molecules were orientated with the hydrophilic part buried in the water and the hydrophobic part away from the water (Frenkiel 1956). Langmuir reached the same conclusion during his work in the 1920s. He reasoned that oils consisting of an aliphatic chain with a hydrophilic end group (perhaps an alcohol or acid) were oriented as a film one molecule thick upon the surface of water (monolayer film), with the hydrophilic group down in the water and the hydrophobic chains clumped together on the surface (Alamaro 2010).

Although many studies on evaporation suppression have been performed using monolayers, there are other techniques available. These techniques focus on impacting the six factors that affect evaporation rates: wind velocity, temperature, surface area, humidity, vapor pressure, and molecular forces. The studies have used a variety of techniques that including:

- wind barriers
- water surface shades
- partial floating covers
- underground storage (CWC 2006).

2.3 Monolayer Films

Monolayer films are very thin films that are one molecule thick and when placed on a water surface form a phase boundary between the air/water interface (Barnes 2008). By creating a boundary layer, the interaction between water vapor and the overlying air is limited, thereby reducing evaporation rates (Barnes 2008). Monolayers are typically compounds of long chain fatty alcohols such as cetyl alcohol (hexadecanol) and stearyl alcohol (octadecanol) (Barnes 2008). Over the past 100 years, there has been a great effort to quantify and measure the effectiveness of monolayer film evaporation suppression. Much of the work was done during the 1950s and 1960s. These studies varied from a period of a few days to several months. Field investigations were conducted on a variety of water body sizes ranging from 2 feet in diameter to 2,500 acre lakes. Many credit Mansfied, an Australian Physical Chemist, as the first to perform evaporation suppression field investigations (Roberts 1957).

2.3.1 Chemical Composition

The chemical composition of monolayers typically consists of two parts: a hydrophilic and hydrophobic (Barnes 2008). The hydrophilic portion of the molecule is strongly attracted to water and forms a transient bond with water through hydrogen bonding (Kirk and Othmer 2000). The bond causes the molecule to anchor itself to the water and helps to prevent other molecules from piling on top of one another (Barnes, 2008). The hydrophobic portion of the chemical compound repels itself from water. These molecules tend to be non-polar and prefer other neutral molecules and non-polar solvents (Kirk and Othmer 2000). Hydrophobic molecules usually include alkanes, oils, fats, and greasy substances in general (Kirk and Othmer 2000). This portion of the monolayer renders the whole molecule insoluble, which is critical when trying to maintain a constant layer over a water surface (Barnes 2008).

A variety of different monolayers have been used in evaporation suppression studies. Long-chain hydrocarbon alcohols such as hexadecanol (cetyl alcohol) and octadecanol (stearyl alcohol) are the two most common used in field experiments. Hexadecanol, $C_{16}H_{34}O$, is a solid organic compound that is a member of the alcohol class of compounds and at room temperature is in the form of a waxy white solid or flakes (Kirk and Othmer, 2000). Originally hexadecanol was produced from whale oil but is now primarily produced as an end-product of the petroleum industry, or produced from vegetable oils such as palm oil and coconut oil (Kirk and Othmer, 2000). Octadecanol, $C_{18}H_{38}O$, is very similar to hexadecanol. It is an organic fatty alcohol compound which occurs naturally in sperm whale oil (Kirk and Othmer, 2000). Similar to hexadecanol, it usually takes the form of white solid granules or flakes which are insoluble in water (Kirk and Othmer, 2000). Figure 2.1 and Figure 2.2 below show the molecular structure of the two alcohols.

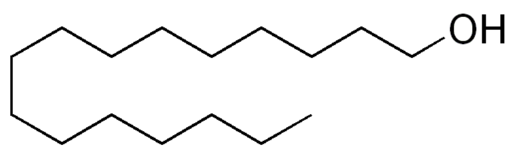

Figure 2.1 Hexadecanol

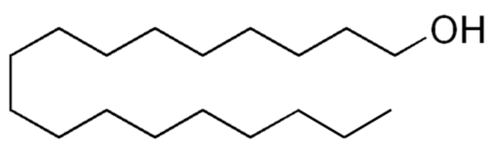

Figure 2.2 Octadecanol

2.3.2 Monolayer Evaporation Resistance

The evaporation rate of water is governed by the driving force for evaporation and total permeation resistance of the transport pathway in an equation analogous to Ohm's law for electrical conduction:

$$J = \frac{\Delta C}{\sum r}$$

where J = evaporative flux (kg/sec m^2), ΔC = the difference in equilibrium vapor concentration for the surface layer of water and the actual vapor concentration in the atmosphere some distance above the surface (kg/m^3), and Σr = the total evaporation resistance (sec/m) (Barnes 1993). Total evaporation resistance is described as a set of component resistances in series with one resistance for each segment of the transport pathway (Barnes 1993). For an untreated water surface the resistance is Σr_w (w for water) (Barnes 1993). Once a monolayer is added to the water surface the total resistance is increased by r_m (m for monolayer) (Barnes 2008). Monolayer resistance is an intrinsic property which is a function of surface pressure, temperature, and the composition of the monolayer and is independent on conditions of measurement such as the driving force. (Barnes 2008). Thus, the total resistance of a treated water surface with a monolayer film is expressed as:

$$\Sigma r_f = \Sigma r_w + r_m$$

Monolayer performance is related to evaporation resistance by the following equation:

$$\varphi = \frac{J_w - J_f}{J_w}$$

where the fluxes J_w and J_f refer to evaporation through a monolayer-free water surface and a monolayer-covered surface (Barnes 1993). By examining this equation, it is apparent that the evaporation reduction achieved is not only dependent on the resistance of the monolayer (r_m) but on the resistance of the other section of the transport pathway (Σr_w) (Barnes 1993). Thus, the higher the value of Σr_w the less of an impact r_m has on reducing evaporation (Barnes 1993). Therefor the monolayer is most effective when Σr_w has a low value.

2.3.3 Methods Used to Estimate Lake Evaporation and Evaluate Evaporation Savings

In order to evaluate the impact of evaporation suppressants on water supply reservoirs it is important to quantify the amount of water lost. There are a variety of techniques used to estimate evaporation loss from free water surfaces. These methods include the pan coefficient method, the water budget method, combined energy budget and mass-transfer method, and the simplified method. Each method requires different metrological input and datasets resulting in various degrees of accuracy. The methods are designed to estimate reservoir evaporation with and without the presence of monolayer films, enabling water savings to be calculated.

Pan Evaporation Method

The pan coefficient method is one of the oldest, simplest, and fastest ways to estimate reservoir evaporation. It was developed on pan evaporation principles which are used to estimate the evapotranspiration (ET) of crops. The pan evaporation method uses a reference pan, typically a Class A pan, which is installed on a wooden support and placed in an open grassy location, away from obstacles that may obstruct natural air flow around the pan. A coefficient (*k*) is given to the pan based on the type of pan (class), size and state of upwind buffer zone (fetch), wind speed, and mean relative humidity (Allen et al. 1998). Once the pan coefficient is determined, the evaporation rate (*Es*) is calculated from daily evaporation and precipitation measurements obtained from a micrometer. The two coefficients, *k* and *Es*, are multiplied to determine the amount of water evaporated (mm/day) for a particular area (Allen et al. 1998).

When applying this principle to estimate evaporation on large bodies of water, their varying characteristics must be accounted for. Two methods, pan coefficients and pan conversions, are used to relate pan evaporation to large water bodies so lake evaporation can be estimated. The first method takes into consideration that evaporation from surface pans tends to exceed the total amount of evaporation from large water bodies. To make the appropriate adjustments, annual lake evaporation estimates are obtained by multiplying the annual pan data by an appropriate coefficient (Jensen 2010). These coefficients are a ratio of water body evaporation to pan evaporation and represent the slope of a plotted pan evaporation against the change in reservoir level (Frenkiel 1965).

The pan coefficient method has been used by the USGS to estimate lake evaporation at Lake Hefner. Based on data obtained during Lake Hefner evaporation studies Kohler (1954) determine that the annual pan coefficient was 0.69. The coefficient varies from location to location but generally ranges from 0.6 to 0.8 with a majority of the values in the 0.7 to 0.75 range (New Mexico Climate Center 2002). Kohler determined that monthly pan coefficients varied greatly because of the temperature lag in the lake due to differences in energy storage capacities between the two water bodies (Jensen 2010). As a result of Lake Hefner evaporation studies Kohler (1954) concluded that annual lake evaporation could be estimated within 10-15% by applying an annual coefficient to pan evaporation provided lake depth and climate regime are taken into account in selecting the coefficient.

In an effort to address short period inefficiencies of the coefficient method, the pan conversion method was developed. This method applies a simple conversion relationship to daily pan readings, by assuming that lake or pan evaporation is proportional to the vapor pressure difference between the respective water surface and some convenient observation height in the air (Webb 1966). The pan conversion equation is expressed as:

$$\overline{E} = K\frac{(\overline{e_s}^{*}-\overline{e})}{(\overline{e}_p-\overline{e})}\overline{E}_p$$

where $\bar{E}$ = mean evaporation rate from the water body, $\overline{E_p}$ = mean evaporation rate of the pan, K = empirical constant, $\overline{e_s}^{*}$ = mean saturated vapor pressure of the air at the water surface temperature, $\overline{e_p}$ = mean saturation vapor pressure at pan surface temperature, and $\bar{e}$ = mean vapor pressure of the air at reference height (Jensen 2010). The empirical constant, K, incorporates not only the ratio of the difference values of pan and lake coefficients, but also the ratio of wind speeds (Jensen 2010). The empirical constant, *K*, is the slope of the straight-line regression coefficient of the plotted daily lake evaporation against the following equation:

$$\frac{(\overline{e_s}^* - \bar{e})}{(\overline{e_p} - \bar{e})} \overline{E}_p$$

Water Budget

Conceptually the water budget is among the simplest methods available for computing open water evaporation. However, its components require several measurements and observations. The water budget is based on the change in volume of water stored and the difference between inflow and outflow:

$$\Delta Storage = Inflow - Outflow$$

The inflow term is composed of precipitation on the water surface, runoff, channel inflow, groundwater inflow, and any other diversion into the body of water being studied. Outflow typically consists of evaporation from the water surface, channel outflow, groundwater outflow (seepage), and any diversion out of the body of water. Based upon given inflow and outflow information the water balance equation can be expressed as:

$$E = P_r + R + Q_i + G_i + D_i - Q_o - G_o - D_o - \Delta S$$

where E = amount of water evaporated, P_r = precipitation on the water surface, R = runoff inflow, Q_i and Q_o = major channel flows into and out of the water body, G_i and G_o = groundwater inflow and outflow, D_i and D_o = diversion into and out of the body of water, and ΔS = change in storage (Jensen 2010).

The accuracy of the method depends primarily on the relative magnitudes of the terms (Jensen 2010). It is difficult to obtain a reliable estimate whenever the evaporation is of the same order of magnitude as errors in the measurements (Jensen 2010). Therefore this method is unsuited for water bodies with large flow rates.

Terms found in the water balance equation can be measured in a variety of ways. Precipitation measurements are usually obtained from raingauges located around the reservoir. When available, channel flows can be obtained from streamgauges or from other stream flow measuring devices. Surface runoff inflow is difficult to determine but can be calculated using methods such as the NRCS Curve Number method. Groundwater and seepage inflow and outflow are also difficult terms to estimate. Techniques used to estimate these terms include using Darcy's law groundwater equation or using USGS MODFLOW to model groundwater movement.

Combined Energy Budget and Mass-transfer Method

Harbeck and Koberg (1959) developed an alternative method to estimate reservoir evaporation using energy budget and mass transfer techniques. The energy budget method is based on the conservation of energy principle which states that energy cannot be created or destroyed and is thus conserved in a system. When applying this to surface water reservoirs, the energy which comes into a water body must be equal to the gain in energy stored by the reservoir plus the amount of energy leaving (Gunaji 1965). Thus, the energy budget method for water reservoirs is typically expressed as:

$$\left(Q_s - Q_r + Q_a - Q_{ar} + Q_v\right) - (Q_{bs} + Q_e + Q_h + Q_w) = Q_o$$

where Q_s = radiation from the sun (cal/cm^2 day), Q_r = reflected solar radiation (cal/cm^2 day), Q_a = incoming long wave radiation from the atmosphere (cal/cm^2 day) Q_{ar} = reflected long wave radiation (cal/cm^2 day), Q_v = net energy advected into body of water (cal/cm^2 day), Q_{bs} = long wave radiation emitted by the body of water (cal/cm^2 day), Q_e = energy used in evaporation (cal/cm^2 day), Q_h = energy conducted from the body of water as sensible heat (cal/cm^2 day), Q_w = energy advected by evaporated water (cal/cm^2 day), and Q_o = increase in energy stored in the body of water (cal/cm^2 day).

The combined energy budget and mass-transfer method assumes that certain items are not affected by the application of a monolayer film to the reservoir surface. This includes all terms grouped as inflow in the energy budget. It is obvious that the film would have no impact on Q_s, Q_a, and Q_v because they are independent of the reservoir water surface. Q_r is also neglected because optical tests have shown monolayer films to have little effect on the reflectivity of the water surface (Harbeck and Koberg, 1959). It is also assumed that any effect of a film on Q_{ar} would be counterbalanced by a change in Q_{bs} (Harbeck and Koberg 1959).

Two other terms, Q_w and Q_v, are excluded in the model developed by Harbeck and Koberg. During energy budget studies at Lake Mead and Lake Hefner it was observed that the energy advected in the evaporated water, Q_w, was extremely small (Harbeck and Koberg 1959). As a result, this term is excluded. Harbeck and Koberg also assumed that over a long period of time, monolayer films have not appreciable effect on the energy stored in the body of water, Q_o. They argued that the initial water temperature rise was limited to the surface of the reservoir (Harbeck and Koberg 1959). Once the initial rise took place the effect of the film on the change in stored energy was negligible (Harbeck and Koberg 1959).

After neglecting various terms in the energy budget, Harbeck and Koberg developed the following equation:

$$\left(Q_{bs}' - Q_{bs}\right) + \left(Q_e' - Q_e\right) + \left(Q_h' - Q_h\right) = 0$$

where Q_{bs}' = long wave radiation emitted by the body of water with a film (cal/cm^2 day), Q_{bs} = long wave radiation emitted by the body of water without a film (cal/cm^2 day), Q_e' = energy used in evaporation with a film (cal/cm^2 day), Q_e = energy used in evaporation without a film (cal/cm^2 day), Q_h' = energy conducted from the body of water as sensible heat with a film (cal/cm^2 day), and Q_h = energy conducted from the body of water as sensible heat without a film (cal/cm^2 day).

Long wave radiation from a body of water, Q_{bs}, can be computed from the Stefan-Boltzman law for black-body radiation (Anderson 1954). The emissivity of a body of water can be evaluated by direct measurement or indirectly from a measurement of the reflectivity of the water surface (Anderson 1954). The direct method consists of heating the water sample and taking measurements of the surface temperature with a thermocouple and radiation from the surface with a directional radiometer (Anderson 1954). The indirect method consists of measuring the reflectivity of the water surface, using calibrated energy sources of different temperatures (Anderson 1954). The resulting long wave radiation from a body of water is:

$$Q_{bs} = r\sigma(T_o+273)^4$$

where r = the reflectivity of the water, σ = the Stefan-Boltzman constant for black body radiation, and T_o = the water surface temperature (ºC) (Harbeck and Kober 1959).

The energy utilized in evaporation, Q_e, is expanded using the mass-transfer equation in the following form:

$$Q_e = Nu(e_o-e_a)$$

where N = an empirical constant obtained during pretreatment calibration (cal/cm^2 day mph°C), u = wind speed (mph), e_o = saturation vapor pressure at T_o, and e_a = water vapor pressure in the air. Q_h, energy conducted from the body of water as sensible heat, can be expanded to represent a heat-transfer equation as:

$$Q_h = Ku(T_o'-T_o)$$

where K = an empirical constant obtained during pretreatment calibration (cal/cm^2 day mph°C), u = wind speed (mph), T_o' = observed water surface temperature with film (°C), and T_o = water surface without film (°C).

After making substitutions, the expanded combined equation developed by Harbeck and Koberg becomes:

$$0.970\sigma[(T_o'+273)^4 - (T_o+273)^4] + [Q_e' - Nu(e_o-e_a)] + Ku(T_o'-T_o) = 0$$

The expanded combined energy budget and mass-transfer method has only one unknown, T_o. The remaining terms are determined by basic instrumentation which includes a total hemispherical radiometer, a pyrheliometer, a psychrometer, a water-surface temperature recorder, an underwater thermometer, and an anemometer.

The above equation is a function of T_o since e_o is a single value function of T_o. It can be solved for and the corresponding values of e_o can be substituted in the expanded Q_e equation to give the evaporation that would have taken place had the film not been present (Gunaji 1965). Evaporation reduction can now be determined by considering the actual evaporation as computed in the energy budget method for water reservoirs and the estimated evaporation had no film been present (Gunaji 1965).

The Simplified Method

In an effort to develop a computationally less intensive method Florey, Garstka, and Timblin created the simplified method for computing reservoir evaporation reductions (Barclay el al. 1959). Components of the simplified method include coverage factor, temperature-evaporation reduction factor, wind speed, and water vapor pressure gradient. Each of these variables is typically measured or estimated at three hour intervals (Florey 1962).

The percentage of evaporation savings is computed using the following equation:

$$100\frac{\sum cfu(e_o-e_a)}{\sum u\,(e_o-e_a)}$$

where c = coverage factor or fraction of the lake covered with a fully compressed monolayer, f = temperature-evaporation reduction factor, u = wind speed, and $e_o - e_a$ = the water vapor pressure gradient. Although the simplified method does require measured data, the instrumentation required to obtain these values is significantly less expensive than those required for energy budget method (Fitzgerald and Vines 1963). In addition, pre-calibrations are not necessary and evaporation savings can be computed as data is collected.

2.3.4 Evaporation Suppression Field Experiments

Several field investigations have been performed to quantify the evaporation suppression performance of monolayer films. Studies have taken place domestically and internationally and have also varied in size. Small scale experiments have evaluated the performance of monolayers films on tanks and reservoirs up to 40 acres in size while large scale trails have been performed on reservoirs several thousand acres in size. A majority of large scale filed investigations were performed by the United States Bureau of Reclamation at Lake Cachuma, California, Lake Hefner, Oklahoma, Lake Mead, Nevada, Arizona, and Sahuaro Lake, Arizona.

Small Scale Field Investigations

The first small scale field trials were performed primarily by the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO). These field investigations used hexadecanol alcohols and measured evaporation savings using evaporimeter pans ranging from 1 to 3 feet in diameter (Roberts 1957). Although several reduction percentages were reported they typically ranged from 15 to 40% (Roberts 1957).

Additional small scale field experiments were conducted by the Illinois State Water Survey during 1956. The first set of studies measured evaporation savings using Class A pans that were 2 feet in diameter and 1 inch deep (Roberts 1957). Through the use of a hexadecanol monolayer film an average reduction of 10% was recorded form July 1 to September 20, 1956 (Roberts 1957). The second study evaluated evaporation savings using two 55-gallon drums which were buried in the ground. One container was filled with plain water and the other was applied with 1 mg of hexadecanol (Roberts 1957). Hook gages were used to report evaporation savings. During July 1 to September 20, 1956 a reduction of 27% was recorded (Roberts 1957). The last investigation was performed from August to October 1986 and made use of 100,000 gallon capacity tanks 30 feet in diameter and 14 feet deep (Roberts 1957). A 33% reduction was computed from August 30 to September 7 using a Class A evaporation pan; a 24% reduction occurred from September 14 to 23 and 11% from October 11 to 18 (Roberts 1957). The study found that the highest levels of reduction were achieved during the first few days of hexadecanol application.

The Illinois State Water Survey performed studies on two adjacent lakes in central Illinois during the summers of 1957 and 1958 (Roberts 1959). The northern lake was 2.8 acres and the southern lake was 2.3 acres. Various forms including flakes, beads, and powders, of hexadecanol and octadecanol were spread on the northern lake (Roberts 1959). Application techniques included mesh-float containers, boat application, and continuous application. After examining the August 1957 water records a 43% reduction in evaporation was reported (Roberts 1959). In 1958 a field investigation was performed on the southern lake during the months of May through August. During this period a 22% reduction was reported (Roberts 1959). Below normal temperatures and high amounts of rainfall produced small reductions in evaporation.

A study sponsored by the Central Water and Power Commission, the Council of Scientific and Industrial Research, and the Government of India investigated evaporation savings produced by cetyl alcohol monolayers in 1962. A medium sized tank with a depth of 11 feet and surface area of 28.2 acres called the Buderi Tank was chosen for the studies (Walter 1963). Cetyl alcohol was applied from a number of shoreline dispensers moored around the perimeter of the lake (Walter 1963). The material was applied consecutively for 7 to 8 days during daylight hours (Walter 1963). Appropriate adjustments were made to the application rate based upon wind speed and current monolayer coverage. The goal was to establish a complete film-coverage over the reservoir to achieve maximum evaporation suppression. A 21% reduction from October 3 to 7, 1963 was computed using the simplified method (Walter 1963).

Over the last 10 years, several evaporation suppression studies have taken place in Australia. The focus has been to identify techniques that reduce water losses from farm storage tanks and reservoirs. The Queensland Government Department of Natural Resources and Mines (NRM) have centered their studies on irrigation areas in northern Australia because evaporation rates are higher than in the southern regions. NRM estimates that annual evaporation losses in the region could be as high as 40% which equates to an annual loss of 810,000 acre-feet and is sufficient to irrigate about 309,000 acres (Craig et al. 2005).

Investigations in Australia have evaluated the performance of Water$avr, a commercially available surface water evaporation control product. Water$avr is a white powder that is a blend of calcium hydroxide (hydrated Lime), and food grade steryl and cetyl alcohols (organic hydroxy alkanes) which forms a one molecule thick film or monolayer on the water surface (Craig et al. 2005). Field investigations using Water$avr have been performed on Australian storage facilities at Capella and Dirranbandi. Storages at Capella are part of a local municipal water supply for Peak Downs Shire Council and has a water surface area of 10.4 acres. The Dirranbandi storage facility has a water surface area of 296.5 acres. Monolayer material was applied by hand on the Capella storage facility at a rate of 0.34 pounds per acre on March 2, 4, 7, 2005 (Craig et al. 2005). Results showed no reduction in evaporation for the period of February 3, 2005 to September 3, 2005 (Craig et al. 2005). Poor performance can generally be attributed to the monolayer being broken down by ultraviolet light, consumed by algae or bacteria, or poor distribution across the water surface. Factors that affect the distribution of the monolayer are typically wind/weather, waves and any physical barriers. Water$avr was applied at the Dirranbandi facility by an applicator developed by Bio-Systems Engineer. The system used water from the storage to carry and distribute the monolayer across the water surface. The grid system had nine outlets evenly spaced over the entire water surface area (Craig et al. 2005). The monolayer was applied at 0.45 pound per acre every second day from November 1, 2004 to July 11, 2004 (Craig et al. 2005). The average amount of evaporation saved was 19%.

Additional suppression studies were performed in early 2006 at Korong Vale, a 10 acre reservoir located in North-Central Victoria. The field trial was performed for a 4 week period and applied Water$avr at a rate of 3.09 pounds per day (Flexible Solutions 2006). Application was made using an automated spreader that made use of an electronic regulator. Results from the field trial demonstrated a 29% evaporation reduction over a 3 week period from February 27, 2006 to March 20, 2006 (Flexible Solutions 2006).

Water$avr evaporation suppression capabilities were evaluated on two agricultural open water reinforced concrete reservoirs located in the Slouge area to the west of Benghazi City in Libya (Ikweiri et al. 2008). The reservoirs are 32 feet in diameter and are 11.5 feet deep. Material was applied to the water surface by hand at a rate of 8.737 pounds per acre (Ikweiri et al. 2008). Results from the experiment show that a 16.42% reduction was achieved from September 1, 2007 to October 16, 2007 (Ikweiri et al. 2008).

United States Bureau of Reclamation Large Scale Field Investigations

Several large scale field experiments were conducted by the United States Bureau of Reclamation during the 1950s and 1960s. These investigations evaluated the performance of monolayer film retardants on reservoirs thousands of acres in size.

Application methods, film coverage evaluation, environmental impacts, and evaporation savings were studied in these water loss investigations.

In 1958 a series of evaporation suppression experiments were performed on Lake Hefner. The 2,500 acre lake is located in Oklahoma and is part of a municipal water supply system for Oklahoma City (Garstka 1959). It was selected for field tests because of several factors including size, geographic location, meteorologic conditions existing during the summer and early fall months, and most significantly a detailed water budget including evaporation losses had been performed (Garstka 1959). A commercially available high quality hexadecanol material was selected as the monolayer forming material because it was commercially available, had previously demonstrated an ability to reduce evaporation, and was determined non-toxic by the Public Health Service (Barclay et al. 1959). The chemical was applied 7 days a week during day light hours as a dry powder that was mechanically suspended in water and sprayed onto the surface of the lake. During the summer of 1958, a total of 40,040 pounds of hexadecanol was applied to Lake Hefner (Barclay et al. 1959).

One objective of field investigations was to evaluate monolayer film coverage across the reservoir. Three methods were used to determine the extent of monolayer film coverage on the water surface. The first method used aerial photographs taken from 1,000 feet, 6,000 feet, and 13,000 feet above the lake by the United States Air Force (Florey et al. 1959). This method encountered issues detecting the film during periods of calm wind conditions (Florey et al. 1959). As a result observation points nearly 100 feet above the water surface were used. At these locations the monolayer film was visually mapped using indicator oils to verify the suspected locations (Florey et al. 1959). The last and most commonly employed method was to simply drive around the lake and observe the location of the film by sighting landmarks on the opposite shore (Florey et al. 1959).

Based upon film detection observations the maximum average coverage for any one day was 62% (Timblin and Floery 1959). The average daily coverage for the 55 days of treatment was 16% while the average daily coverage for the entire 86 days of the application phase was 10% (Timblin and Floery 1959). It was determined that wind speed greatly affect film coverage. Winds up to 11 mph were helpful in establishing the monolayer but as the speed increased it became more difficult to maintain the film (Timblin and Floery 1959). At wind speeds greater than 20 mph it was impossible to maintain any film coverage (Timblin and Floery 1959). Timblin and Florey (1959) stated that biological consumption and wave action contributed to poor film coverage.

Evaporation savings were computed using the combined energy budget and mass transfer method and the simplified method. Based on the combined energy budget and mass transfer computation an evaporation reduction of 9% was determined for the 86 day test period (Price et al. 1959). However for shorter periods within the 55 days, savings from 10 to 14% were achieved (Price et al. 1959). Evaporation savings of 3.4% were computed using the simplified method (Price et al. 1959). Although low reductions were computed, laboratory experiments conducted concurrently with Lake Hefner treatments indicated that 35% reductions could be achieved under ideal conditions. This includes constant coverage and water surface temperatures recorded at the prevailing temperature (Price et al. 1959).

In 1960 evaporation reduction studies were conducted at Sahuaro Lake by the Bureau of Reclamation in cooperation with the Salt River Valley Water Users' Association and the U.S. Geological Survey (Florey 1961). Sahuaro Lake is located on the Salt River, 41 miles east of Phoenix, has a surface area of 1,000 acres and stores 69,000 acre-feet of water (Florey 1961). The focus of the study was to test new methods of applying monolayer films to large water surfaces, to test various monolayer forming materials, and to observe the efficiency of the monolayers under conditions different from those encountered at Lake Hefner (Timblin and Florey 1961).

Two methods of application were used to apply powdered octadecanol-hexadecanol mixture to the lake surface. The first method applied a powdered material using eight automatic dispensers that stored the melted alcohol under pressured and maintained it in the molten form (Florey et al. 1961). The second application method made use of a dusting technique where two small gasoline-powered blowers mounted on boats dispersed a fine powder as they traveled across the lake (Florey and Hansen 1961).

Before evaporation savings could be computed an evaluation of film coverage was required. The location of the monolayer was visible and could be easily photographed for wind speeds between 12 to 15 mph (Florey et al. 1961). Similar to Lake Hefner studies, film detection was difficult in calmer conditions. Four F-101 reconnaissance planes provided by the United States Air Force were used to take aerial photographs (Florey et al. 1961). There were some difficulties identifying the monolayer using the aerial method and as a result it was determined that slightly different angles gave a better indication of film coverage than others. Therefore visual mapping techniques should still be combined with aerial photographs.

Evaporation reduction performance was evaluated using the combined and simplified method. A 14% reduction was computed from October 1 to November 17, 1960 using the combined method (Koberg 1961). From October 19 to November 17, 1960 an evaporation reduction of 22% was calculated (Koberg 1961). For the period of October 1 to November 17, 1960 a 19% reduction was computed using the simplified method. Additionally evaporation savings of 23% were reported from October 19 to November 17, 1960 (Koberg 1961).

During the summer of 1961 a full scale field investigation was conducted at Lake Cachuma, California. The 3,090 acre reservoir is located about 25 miles northwest of Santa Barbara, is 8 miles long and when full has a storage capacity of 205,000 acre-feet (Hamburg 1962b). A tallow-based hexadecanol and octadecanol material specifically manufactured for evaporation reduction purposes was used in the evaporation suppression study (Hamburg 1962b). The material consisted of the following composition:

- C18 – 6.2 percent, octadecanol
- C16 – 30.4 percent, hexadecanol
- C14 – 3.3 percent, tetradecanol
- C12 – 0.1 percent, dodecanol (Hamburg 1962b).

The material was applied using automatic dispensing units located at strategic points on the lake (Hamburg 1962b). The amount of material applied was 59,650 pounds and was applied between July 20 and September 25, 1961 (Hamburg 1962b). Similar to the Lake Hefner studies, an evaluation of film coverage was performed. Film coverage was evaluated at 960 feet above the lake surface because it provided a good view of the lake surface with the minimum and maximum distances to lake being 1 mile and 3 1/4 miles (Newkrik 1962). This survey station was used as a reference to plot the position of the film on U.S. topographic maps placed on an 18 by 24 inch plan table board (Newkrik 1962). This provided an accurate method for documenting the film coverage. Similar to Lake Hefner investigations the monolayer film was difficult to detect during calm conditions. During periods of light wave action the film was detectable because the water appeared to be smoother than surrounding areas not covered by the monolayer (Newkrik 1962).

The Lake Cachuma studies found that film coverage is highly dependent on wind speed. When wind speeds were greater than 15 mph it was impossible to replenish the film blown onto the downwind shore (Newkrik and Hansen 1962). Winds ranging 15 to 20 mph caused the film to form into 5 to 10 foot wide strips running from each dispenser (Newkrik and Hansen 1962). The studies revealed a well-developed wind pattern each day, rising at about 8:00 a.m. from 3 to 5 mph during the night to about 15 mph in the afternoon. As a result, an average coverage of 60% occurred early in the morning and 20% in the late afternoon (Newkrik and Florey 1962).

Evaporation savings were computed using the combined method and the simplified method for the period of July 24 to September 24, 1961 (Koberg 1962). The combined method calculated a savings of 257 acre-feet which was an 8% reduction in evaporation. However during the Sahuaro Lake studies Koberg (1962) discussed the possibility of energy being stored in the lake as a result of application of the film. In order to eliminate any uncertainty, evaporation savings were computed for a longer period from July 31 to October 23, 1961 (Koberg 1962). The additional month would allow any stored energy to dissipate after film application had stopped. Based on the additional month Koberg (1962) reported a reduction of 170 acre-feet. Savings computed using the simplified method reported a reduction of 19% for the period of July 24 to September 24, 1961 (Koberg 1962).

2.3.5 Application

There have been a variety of methods used to apply monolayer films to reservoirs surfaces. Methods include gravity drip techniques, manual application using powdered hexadecanol, automatic spray dispenses, and aerial application.

Mansfield outdoor trials of 1956 applied monolayer films by using gravity drip containers placed on the water surface. Containers consisted of 40-gallon drums filled with solid small flakes of cetyl alcohol (Frenkiel 1965). The containers were anchored to rafts fitted with wire gauzed sides so the material could drop on the water surface. (Frenkiel 1965). Beaded cetyl alcohol was also used because it had a stronger structure

(Frenkiel 1965). After performing several field experiments, it was found that gravity drip containers were only suitable for reservoirs up to two acres in size (Frenkiel, 1965). A similar method of application was used in 1956 by the Illinois State Water Survey. Four wooden hexadecanol distributors with a 12-mesh copper screen wire were used to apply the monolayer material (Roberts 1957). The gravity mesh-float containers were also used in the 1957 central Illinois studies.

Solvent application methods were experimented with at Stephen's Creek in Australia and by the United States Bureau of Reclamation. This method dissolved cetyl alcohol in a volatile petroleum fraction and ethyl alcohol. It was then applied by means of a gravity feed through fine-gauge piping from calibrated 40-gallon drums (Frenkiel 1965). The United States Bureau of Reclamation rejected using this method on account of health, fire hazards, and interference with any possible or potential recreational use of the reservoir (Frenkiel 1965).

Following early application methods the United States Bureau of Reclamation experimented with various manual application methods at Ralston Creek Reservoir, Sahuaro Lake, Lake Hefner and Lake Cachuma. Powdered hexadecanol was applied to the surface of Ralston Creek Reservoir by dusting the surface from a boat traveling across the lake (Timblin et al. 1959). The material was first applied at a rate of 0.3 pound per acre per day. After a film had been established, applications were made at a rate of 0.1, 0.2, and 0.4 pound per acre per day (Timblin et al. 1959). The Ralston Creek studies found that an application rate of 0.2 to 0.4 pound per acre per day was required to maintain the maximum film coverage (Timblin et al., 1959).

The 1958 field experiments at Lake Hefner also made use of powdered hexadecanol. However instead of blowing the material directly on the water surface it was mechanically mixed and suspended in water then sprayed onto the surface of the lake (Barclay et al. 1959). Two separate identical dispensing units were used to apply the film. The dispenser consisted of two 55-gallon mixing chambers powered by a single engine through a pulley and clutch arrangement (Barclay et al. 1959). A second engine powered the intake and discharge pumps that would pump water from the lake into the mixing chamber (Barclay et al. 1959). The powder and water were mixed into a slurry and sprayed onto the water surface. The dispensing units were mounted on a 17-foot boat and the other mounted on a floating platform supported by four pontoons, propelled by a 25-horsepower motor (Barclay et at. 1959). The rate of application varied from about 0.1 pound per acre per day to nearly 0.5 pound per acre per day (Barclay et al. 1959).

The powdered dusting technique was used in the Sahuaro Lake and Lake Mead studies of 1960. A mixture of hexadecanol and octadecanol was dispensed on the water surface through small gasoline-powered blowers (Florey and Hansen 1961). The blowers were mounted on two boats and began dusting on the windward side as they traversed the lake in a serpentine pattern perpendicular to wind direction (Florey and Hansen 1961). It was found that in light winds of about 7 to 8 miles per hour or less the entire lake could be covered in 1 to 2 hours (Florey and Hansen 1961). This technique was practical because the powdered material is easily handled, required no mixing, and the rate of application could be easily adjusted by varying the boat speed or the rate of feed to the blower (Florey and Hansen 1961). Florey and Hansen (1961) reported a few disadvantages which included the tendency of the powder to lump together, and melt inside the blower when temperatures were hot.

Although the manual powdered applications proved to be successful there was a desire for automatic dispensing units. Sahuaro Lake studies of 1960 used eight automatic dispensing units (Florey et al. 1961). The dispensers consisted of a hot-water tank which held melted alcohol and an electrically controlled valve (Florey et al. 1961). The electrical valve was programmed to only open the distribution value when an offshore wind was blowing, regulate the dispensing rate, and stop when the wind speed was near zero (Florey et al. 1961). The application rate was regulated by the length of time the valve remained open. This varied from 0.2 to 1.5 seconds (Florey et al. 1961). Once the material was released into the air it turned into a fine powder and was carried by the wind for several yards out (Florey et al. 1961). This method of application was selected because fine powder material was more expensive than in solid form and it was much easier to regulate the flow of melted material (Florey et al. 1961). The average application rate was 0.29 pound per acre day (Hamburg 1962b).

Automatic dispensing equipment was used in the 1961 Lake Cachuma evaporation study. This method of dispersion was selected in an effort to overcome many of the problems encountered in previous evaporation reduction studies (Florey et al. 1962). The main issues addressed were the influence of wind on monomolecular film application, difficulties of handling commercial monolayer-forming materials such as finely divided powders, high costs of manual applications and difficulties in shipping and handling the material (Florey et al. 1962). Although the dispensers were relatively identical to those used at Sahuaro Lake there were a few key improvements. Instead of using gas burners to heat the tanks the use of electrical heaters was implemented. The purpose of this was to solve the difficulty in keeping the pilot-light lit in field operations. In addition the spray nozzle was electrically heated to prevent the freezing of the monolayer between spray bursts (Florey et al. 1962). In this study an anemometer served as a switch to trigger a circuit which controlled the solenoid valve (Florey et al. 1962). Similar to previous studies, the rate of application was proportional to the wind speed. A controller setting of 1 second for each 1/60 mile of a wind was used. Therefore a 10 mph wind would trigger the circuit every 6 seconds (Newkirk and Florey 1962). This resulted in an average application rate of 0.37 pound per acre day (Hamburg 1962b).

In 1961 the United States Bureau of Reclamation and Utah State University explored the feasibility of applying evaporation suppressant material from the air. The chemical was applied by a method developed by Israelsen and Hansen of Utah State University which made use of dispensers that could use retardants in liquid or powder form (Gunaji 1965). The two dispensers were tested at Elephant Butte reservoir. Results indicated that a particle-diameter size of 75 to 200 microns were best suited for aerial application (Frenkiel 1965). Particles smaller than 75 microns tended to be carried past the reservoir surface by wind while particles larger than 200 microns were less effective in film formation (Frenkiel 1965). It was concluded that the use of aircraft to apply evaporation retardants appeared to be effective.

2.3.6 Spreading Properties and Rates

An important property of monolayers is the ability to spread quickly over water surfaces. Past field experiments stress that the alcohols selected should be able to form a monolayer readily on the water surface (Frenkiel 1965). They must also be able to continually reform as a result of being broken apart by wind, wave action and biological decomposition. There has been an extensive amount of laboratory work on spreading properties such as the spreading process, influence of alcohol phase form, equilibrium spreading pressure, and collapse pressure.

The monolayer spreading process is composed of two steps: transfer from bulk solid to monolayer on the water surface, and the movement of monolayer across the surface (Barnes 2008). The spreading rate from bulk solid to monolayer is proportional to the length, l, of the line of contact between solid particles and water surface and also depends on the driving force (Saylor and Barnes 1971). The driving force is expressed as:

$$\frac{dN}{dt} = k_{sp}(\Gamma_e - \Gamma)$$

where k_{sp} = spreading rate constant, l = the length of the solid/water/air triple interface, Γ_e = equilibrium surface concentration of the monolayer with respect to bulk solid, and Γ = actual surface concentration (Saylor and Barnes 1971).

In examining spreading rates, it was determined that the phase of long-chain alcohols impacts bulk spreading rates. Normal long-chain alcohols with an even number of carbon atoms can exist in three polymorphic forms: α (transparent), sub-α (translucent), and β (opaque) (Saylor and Barnes 1971). At room temperature the stable form of pure alcohols is the opaque β phase, whereas the stable form of alcohols mixed with other compounds is the sub- α phase (Saylor and Barnes 1971). When water or some long-chain alcohols (notably octadecanol) are added to mixtures, the β phase is suppressed in favor of the sub- α phase (Frenkiel 1965). Studies performed by Vines and Makins (1959) and Stewart (1960) found that alcohols in α phase spread more slowly than those in sub- α phase (Frenkiel, 1965).

The alcohol chemical composition used to form monolayers has an impact on spreading rates. In a study by Deo, Kulkarni, Gharpurey and Biswas (1961) the spreading rate of various long-chain alcohols and alkoxy ethanols were evaluated. Samples used in measurements were prepared by dipping and gently withdrawing a glass rod of uniform diameter from the melt of a substance (Deo et al. 1961). The rods were then allowed to age at least two weeks (Deo et al. 1961). Spreading rates were determined by half immersing the rods in a known area of clean water and were calculated based the time required for the film pressure to rise to the low value of 1 dyne/cm. Results indicated that the spreading decreased as the chemical composition chain length increased (Deo et al. 1961). Test result also showed that the spreading rate for the alkoxy ethanols in the range (C_{16} to C_{22}) were one order of magnitude greater than that of the corresponding alcohols (Deo et al. 1961). Results from this study are provided in Table 2.1 and Table 2.2.

Table 2.1 n-Fatty Alcohols

Chemical Composition	Melting Point °C	Spreading Rate (Number of Molecules/cm/sec)	Equlibirum Spreading Pressure (Dynes/cm)
C_{14}	39.5	2.1×10^{15}	46.5
C_{16}	49.5	2.81×10^{13}	39.6
C_{18}	59.4	1.1×10^{12}	35.2
C_{20}	64.5	7.6×10^{11}	32.6
C_{22}	71.0	6.0×10^{11}	27.6

Table 2.2 n-Alkoxy Ethanols

Chemical Composition	Melting Point °C	Spreading Rate (Number of Molecules/cm/sec)	Equlibirum Spreading Pressure (Dynes/cm)
C_{14}	35	5.2×10^{15}	48.6
C_{16}	43.5	2.3×10^{15}	50.4
C_{18}	51.7	1.8×10^{14}	48.9
C_{20}	60.5	1.2×10^{13}	49.0
C_{22}	65.6	1.5×10^{12}	47.2

Equilibrium spreading pressure is another property that affects the ability of alcohols to spread and maintain a monomolecular film under compression or expansion. Equilibrium spreading pressure is the surface pressure of a film in equilibrium with a surplus of the solid or liquid film-forming material (Frenkiel 1965). When a crystal of a monolayer-forming material is placed on a water surface it will spread spontaneously until equilibrium between monolayer and crystal is reached at the equilibrium spreading (surface) pressure, Πeq, or until the supply of bulk material is exhausted (Barnes 2008). For most amphiphiles with potential for retarding evaporation it is desirable to have a high surface pressure in order to achieve the highest evaporation resistance and in some cases eject impurities from the monolayer (Barnes 2008). Therefore, materials used to form monolayers should have a high surface pressure in order to achieve the highest evaporation resistance (Barnes 2008). The equilibrium spreading pressure of various monolayer forming materials are listed in Table 2.3.

Table 2.3 Equilibrium Spreading Pressure

	Equilibrium Spreading Pressure	
Monolayer	at 20°C	at 40°C
Hexadecanol	39	47
Octadecanol	35	44
Hexadecanoic acid	8	20
Octadecanoic acid	2	13
Hexadecoxy ethanol	51	-
Octadecoxy ethanol	48	-

In examining spreading properties of monolayer films, studies have also investigated the importance of collapse pressure. Collapse pressure is the film pressure above the equilibrium spreading pressure that causes the monolayer film to collapse (Brooks and Alexander 1962). Studies by Brooks and Alexander (1962) found that in the absence of the stable bulk phase the spreading pressure of the collapsed material depends on the rate at which it has been formed, and the collapsed material always spreads much faster than the stable crystal.

2.3.7 Environmental Impacts

Environmental impacts of monolayer films were evaluated in past field investigations. Studies focused on the potential toxicity to human life, physical and chemical factors influencing aquatic life in reservoirs, and changes in bacterial populations (Frenkiel 1965).

One of the main concerns with using evaporation suppressants on water supply reservoirs is the impact on water quality. This was a particular focus of the 1958 Lake Hefner studies. After reviewing study data it was conclude that there were no apparent toxic effects and there were no undesirable effects on the treatment processes of the lake water resulting from the application of hexadecanol.

Additional efforts were made to determine monolayer film impacts on the water treatment process. The first attempt was conducted in 1957 at the Ralston Creek Reservoir in Denver, Colorado (Barclay et al. 1959). Water samples were collected using a carbon filtration system at the discharge outlet of the reservoir. Samples were collected before and during the application of hexadecanol. Results indicated that there was no obvious difference in the amount of material present. If there was any concentration in the water it was less than 5 parts per billion (Barclay et al. 1959). A similar study was performed during the Lake Hefner field experiments. No hexadecanol could be detected in the finished water (Barclay et al. 1959). This conclusion was also reached at Sahuaro Lake in 1960. No evidence of octadecanol was found on the two filters and if there was the concentration was below 10 parts per billion (Florey -32 1961).

Aside from considering potential toxicity to humans, impacts on aquatic life were included in the investigations. Studies performed by the United States Bureau of Reclamation were divided into two separate phases (Timblin 1957). The first phase consisted of directly investigating the toxicity effect of hexadecanol on fish. Two types of fish were evaluated: cold water game fish such as sing beaver top minnows and warm water game fish, green sunfish (Timblin 1957). Studies were devised so that each time the fish consumed food they would also eat small flakes of hexadecanol (Timblin 1957). It was found that the fish did not demonstrate any severe or acute toxicity from consuming the material (Timblin 1957). The second phase evaluated biological system features of the reservoir which affect the life and health of fish, especially fish food elements such as may files and daphnids (Timblin 1957). May flies were placed in jars with a small volume of water containing a concentration of hexadecanol at 8 pounds per acre. The daphnids were studied in a 250-ml beaker with water containing the same concentration of hexadecanol. Results indicated that the hexadecanol did not interfere with the growth and reproduction of the May flys and daphnid (Timblin 1957).

Physical and chemical effects of monolayer film degradation were another area of focus during field investigations. Physical factors pertain to measurable water qualities such as water temperature. One modeling study performed by Australian researchers suggest that water temperature rises with the application of monolayers (McJannet et al. 2008). This can be contributed to the process of reducing evaporation resulting in a decrease in energy loss from the water body which is manifested through an increase in water temperature (McJannet et al. 2008). It was found that over the course of three years, the average temperature rise for year round application was 2.2 °C. A similar conclusion was reached in the investigations conducted by Barnes in 1993.

The potential impact on bacterial populations was also included in environmental assessments. This was a focus on the evaporation control study performed on Lake Hefner. Results during the early study period indicated that bacterial counts for *Pseudomonas* and *Alcaligenes* increased (Barclay et al., 1959). The bacteria count for each of these reached a maximum of 10 million bacteria per milliliter. It was noted however the water treatment plant did remove a majority of the bacteria. Similar results were obtained in the lab investigations of Chan, Walton, Woodward and Berger. They found that hexadecanol supported the growth of certain bacteria especially the *Pseudomonas* and/or *Flavobacterium* (Barclay et al. 1959). These types of bacteria used the film as a food source and interfered with its repair.

2.3.8 Economic Evaluation

Economic evaluations were performed during studies to determine the feasibility of using monolayer films on large reservoirs. Evaluations considered the type of material used, gasoline, oil, repairs for the operation of boats, salaries and wages of operators and laborers, motor vehicle operation, rental of barge, equipment depreciation, and other costs that occurred during evaporation suppression operations (Riesbol and McDonald 1958).

The United States Bureau of Reclamation studies determined that the main cost of saving water is governed largely by the cost of materials used. Economic evaluations performed indicated that the suppression material accounted for roughly 52% of the total cost. The cost of fatty alcohol used at Lake Hefner was $0.52 per pound, $0.25 per pound at Sahuaro Lake, and less than $0.22 per pound at Lake Cachuma (Riesbol and McDonald 1958; Teter and Florey 1961 and Hamburg 1962a). Lake Hefner studies found that the cost per acre-foot of water saved ranged from about $58 to $86 with an average of $61.21 from July 7, to October 1, 1958 (Riesbol and McDonald 1958). This compares to $60 per acre foot, the value of raw water, as reported by Oklahoma City (Riesbol and McDonald 1958). The cost per acre-foot of water saved at Sahuaro Lake was about $69 from October 1, to November 17, 1960 and $58 from October 19 to November 17, 1960 (Teter and Florey 1961). The cost of water saved at Lake Cachuma was roughly $67.55 per acre-foot. The cost on a daily basis was $0.129 which compares to $0.17 per acre-day at Sahuaro Lake and $0.14 per acre-day at Lake Hefner (Hamburg 1962a).

In performing cost evaluations, the average amount of material used in evaporation suppression studies were reported. The Lake Cachuma test reported that the average material used per acre-day amounted to 0.37 pounds (Hamburg 1962a). This compares to 0.29 pounds used at Sahuaro Lake. The difference is attributed to the method of treatment used and the amount of wind encountered during evaporation suppression studies. All the cost reported were derived on the basis of evaporation savings computed by combined energy budget and mass transfer method.

2.4 Evaporation Reduction Methods

Over the last 20 years there have been additional efforts to suppress evaporation in stock tanks and small water reservoirs. As mentioned earlier, six important factors affect evaporation rates: wind velocity, temperature, surface area, humidity, vapor pressure, and molecular forces. Therefore studies have focused on influencing the factors that cause evaporation rates to increase. Studies have used a variety of techniques which include wind barriers, water shades, floating covers, and other techniques.

2.4.1 Wind Barriers

Wind is one of the most important factors affecting evaporation rates. It is a component of different potential evaporation equations such as the Penman-Monteith equation and pan evaporation. In an effort to reduce evaporation, the government of India has proposed using vegetation as a type of wind barrier (CWC 2006). For this to be accomplished vegetation should be planted in rows normal to the direction of the wind (CWC 2006). Plants typically used as wind barriers include shrubs, medium height broad-leaved trees, medium to tall evergreen trees, and tall broad-leaved trees with conical crowns (CWC 2006). Vegetation selected for wind barriers should be capable of resisting stresses from wind, temperatures, moisture, evaporation, insects, and diseases to avoid constantly being replaced (CWC 2006). Lastly rows should be arranged with the tallest plants in the middle and the smallest along the end rows so that a conical profile is formed (CWC 2006).

In 1961, Oklahoma State University and the Bureau of Reclamation investigated the effectiveness of using floating wind barrier systems to reduce evaporation (Crow 1963). Two identical adjacent ponds, 100 by 120 by 7 feet, constructed on a broad crested ridge were used to determine evaporation reductions (Crow 1963). Two types of wind barrier system were used. The first was an open wind baffle system constructed from a picket type “snow fence” with two inches of open space between the 1 1/2 in pickets (Crow 1963). The second wind barrier was formed by securing vinyl chloride plastics to the pickets of the first barrier. This created a true wind barrier as opposed to the slotted system. The barriers were erected to a height of 0.9 feet with a cable system and placed on 14.5-foot centers with one axis parallel to the prevailing wind (Crow 1963). This subdivided the surface of the pond into 48 small compartments. A 9.1% reduction was achieved for period of May 9 to 27, 1961 with an average wind speed of 10.3 mph.

2.4.2 Water Shades

Water shades have been used to reduce evaporation on water surfaces because they help minimize energy and mass exchanges between the water surface and surrounding air. They have been used in countries such as Australia, Spain, and India. Shade covers are usually used on small water storage facilities because of cost limitations. In a project performed by the Queensland government Department of Natural Resources and Mines (NRM), the performance on a NetPro shade cloth was evaluated. NetPro is a suspended shade cloth that is made from high tension cable and black monofilament cloth which reduces ultraviolet light by 90% (Craig et al. 2005). NetPro was tested on a 3.8 hectare storage tank at Stanthorpe for three weeks (Craig et al. 2005). Test results show that at a height of 0.5 meters above the water surface a 80-87% reduction in evaporation was achieved during the summer months and a 50-56% reduction during the winter months (Craig et al. 2005).

Similar shading material experiments were performed at the Experimental Station of the University of Cartagena in Southern Spain. Studies were performed on Class-A evaporation pans located on an uncultivated field (Martinez Alvarez et al. 2006). The walls and bottom were thermally isolated from the environment by a layer of glasswool wearing one external sub-layer filled with air which helped minimized energy exchanges (Martinez Alvarez et al. 2006). The top and sides of the metallic structure were covered with the following types of porous materials:

- A single layered aluminized net (ALU),

- A single layered black net (BPE),
- A single layered white net (WPE),
- A single layered green net (GPE),
- A single layered blue net (BLPE),
- A doubled layered white net (2WPE), and
- A double layered black net (2BPE) (Martinez Alvarez et al. 2006).

Result showed that following evaporation reductions were achieved:

- 51.5% by ALU
- 75.1% by BPE
- 54.7% by WPE
- 76.2% by GPE
- 77.6% by BLPE
- 68.5% by 2WPE
- 83.5% by 2BPE (Martinez Alvarez et al. 2006).

Another evaporation suppression study was conducted in 2008 using an experimental agricultural water reservoir located at the Agicultural Experimental Station of the University of Cartagena. The performance of a porus suspended cloth that was suspended above the water surface by means of a high tension polyamide cable structure was evaluated (Martinez Alvarez et al. 2010). The cloth was made out of a double layered black polyethlyene mesh fabric (Martinez Alvarez et al. 2010). An annual evaporation reduction of 84.1% was achieved for the months of April 2008 to March 2009 (Martinez Alvarez et al. 2010).

In 1989 evaporation reduction studies were conducted at the Central Arid Zone Research Institute in Jodhpur, India using a 0.25-mm thick white polyethene sheet. Reduction studies were performed on seven cemented tanks partially sunken in the ground at a research farm. The tanks were 200 cm by 200 cm by 100 cm deep and were spaced 200 cm apart (Khan and Issac 1990). The polyethene sheet selected provided 100% coverage of the water surface and reduced evaporation losses by 82% over a 19-month period. Economic results from the study found that the cost of using the shading material was $0.19 per 1000 Liters of water saved (Khan and Issac 1990).

2.4.3 Floating Covers

Floating covers are used as evaporation suppressants because they limit the amount of solar energy entering the water surface and greatly increase the amount of solar energy reflected from the water. In addition, floating covers act as a physical barrier to evaporation, which further reduces evaporation rates (Cooley 1983).

The effectiveness of floating covers were studied on a set of six metal stock tanks, 2.7 meters in diameter and 0.9 meters deep, located near Granite Reef Dam, which is about 50 kilometers northeast of Phoenix, Arizona (Cooley 1983). The tanks were placed on top of the ground in two east-west rows of three each with their sides exposed (Cooley 1983).

The different covers evaluated in the study performed by Cooley include:

- Foamed wax blocks – Irregular white foamed wax averaging about 12 cm in diameter and 4 cm thick. The blocks had a high melting point ranging from 150°F to 165°F and covered about 60% of the water surface.
- Continuous wax – White foamed wax with an average thickness of 0.6 cm was used to form a continuous coverage over the water surface. The wax had a melting point ranging from 120°F to 135°F.
- Foamed rubber – The cover consisted of foamed rubber or sponge made of low-density, closed-cell ethylene propylene diene monomer (EPDM) synthetic rubber about 0.6 cm thick (Cooley 1983). A coverage of 95% was maintained during the study period.

The average evaporation reduction achieved by foamed wax blocks was 36% for an 8-year period while the foamed rubber cover reduced evaporation by 84% over a 4-year period (Cooley 1983). Continuous wax covers reduced evaporation by an average of 80% over a 6 to 7 year period. The wax melted within six-months and was reapplied to maintain 100% coverage. As a result, Cooley (1983) recommends using wax with high melting point temperature to reduce the frequency of reapplication.

Evaporation reduction studies at the Central Arid Zone Research Institute in India evaluated the performance of a floating polyethene sheet, foam rubber sheet, polystyrene sheet, and bamboo. The floating polyethene sheet covered 75% of the water surface and reduced evaporation by 66% (Khan and Issac 1990). The floating foam rubber sheet covered 90% of the water surface area and averaged a reduction of 74% over 19 months (Khan and Issac 1990). The polystyrene sheet covered 98% of the water surface and reduced evaporation by 82% (Khan and Issac 1990). Bamboo material also covered 98% of the water surface but only achieved a 54% reduction over the 19 month test period (Khan and Issac 1990). In evaluating each material's performance, durability and economic value were studied. Fine cracks were noticed on the polyethene sheet at the end of the study because of exposure to large amounts of solar radiation. However, no degradation was noted on the floating foam rubber and polystyrene sheet. Bamboo selected as floating covers proved to be durable but gradually absorbed water over 19 month study which lead to a reduction in suppression efficiency (Khan and Issac 1990). Economic evaluations revealed that the cost per 1000 Liters of water saved was $0.27 for polyethene sheets, $0.52 for the foam rubber sheet, and $0.60 for the floating bamboo.

2.5 Assessment of Evaporation Suppression Studies

This literature review has summarized a range of topics including evaporation, evaporation assessment methods, and evaporation suppression field studies. As a result several assessments, conclusions, and recommendations can be made based on past studies reviewed. Assessments will address the strengths and weaknesses of evaporation assessment methods, inefficiencies of different monolayer materials, monolayer film performance, and application techniques.

Past studies performed by the United States Bureau of Reclamation reveal several inefficiencies of using monolayer films on large surface water reservoirs. The first major concern is film displacement by wind. Practically all suppression trials of monolayers films on open water storages reported problems with moderate to high winds causing film displacement. As a result, evaporation savings dramatically decreased. Vines and Fitzgerald (1963) reported evaporation savings decreased from 10-20% during 10 mph winds to 0% at 15 mph. In order to mitigate the effects of wind displacement, other types of materials should be used. Garret (1971) suggests that more flexible liquid monolayers such as oleoyl alcohol should be used in windier locations to help overcome displacement at high wind velocities. Another option for handling negative wind effects is to select materials that have high equilibrium spreading pressure. This will ensure that materials will initially spread easily when placed on the water surface and repair spontaneously after being broken down by wave action or wind displacement.

Other techniques which can be used to address inefficiencies experienced during high wind speeds is to implement monolayer application systems that can adaptively manage monolayer dosages in response to changing environmental conditions. "Smart" application techniques will help establish constant film coverage resulting in higher evaporation reduction rates. However constantly applying the film to the water surface will lead to higher material costs, resulting in a less economically reasonable solution.

One way to address this problem is to strategically place monolayer material distributors at various points on large water reservoirs. Locations should be on or near the shore along the windward side of the storage so the material can spread in the direction the prevailing winds. By selecting effective application techniques and using more durable monolayers, the frequency, and therefore the cost of application can be reduced (Barnes, 2008).

Another major issue encountered during field investigations is film degradation. This was contributed to numerous factors including bacterial decomposition. Several studies noted that bacteria such as *Pseudomonas* and *Alcaligenes* increased in number because they were able to feed on the breakdown products. Serious film degradation was noted over a 3 to 4 day period (Barnes 2008). This raises a major concern because monolayer material will have to be constantly reapplied to achieve maximum coverage. Future field experiments should address this issue by developing bacteria resistant films or implementing techniques to limit the number of monolayer consuming bacteria in surface water reservoirs.

Material degradation is also a concern in small scale evaporation suppression studies. The most common type of degradation is the result of severe solar radiation exposure. The types of materials affected included floating foam rubber sheets, polystyrene sheets, foam and continuous wax blocks, and water shades. In over to overcome this obstacle, materials selected as evaporation suppressants should have be durable, have high melting temperatures, and be minimally impacted by exposure to solar radiation in order to avoid constant replacement.

Based on inefficiencies experienced during evaporation suppression studies several recommendations can be made in order to achieve maximum evaporation reduction. Materials selected for use should have a high evaporation resistance, high equilibrium spreading pressure, a high spreading rate, resistance to wind stress, slow vaporization rates, resistance to bacterial attack, and resistant to degradation from solar radiation. When considering which evaporation suppression material to use, monolayers are likely to offer the best options for evaporation mitigation on storage greater than 25 acres in size, which is largely contributed to cost effectiveness. Although monolayer films may offer the best option for larger reservoir, reduction rates ranged from 10% to 30%. These values compare to a 15% to 40% reduction experienced in smaller irrigation reservoirs. In order for these values to increase, improvements in the application of monolayer to reduce evaporation from large area of water will need to be addressed.

When considering evaporation suppression techniques on smaller reservoirs, water shades and floating covers are the most promising solutions. In the last 20 years evaporation suppression capabilities of water shades have greatly increased. This is contributed to emerging technology and increased research efforts. A majority of the effort has been led by Australian researches who have evaluated their performance on agricultural water supply reservoirs. Reduction rates from 60% to 90% are typically reported from field experiments. When considering using water shades as a means of current water supplies, an economic analysis should be performed. Water shades require a large startup cost because of installation and material costs. For this reason, water covers are most suitable for smaller permanent water tanks such as those used for agricultural irrigation.

Floating covers are another suppression technique that produces high reduction percentages. Similar to shade cloths typical reductions values ranged from 70% to 90%. Floating covers such as foamed wax blocks should be used for shorter periods of time because of durability issues. Other types of floating covers that aid in suppression include polystyrene and polyethene sheets. These materials are more durable than those previous mentioned but also require replacement because of solar radiation damage. After considering the various reduction methods available combinations of different methods should also be investigated by suppliers. One such combination could possible include floating cover in center of a reservoir surrounded by monolayer or shade cloths.

Evaporation suppression techniques provide a reasonable solution for providing additional water supply capabilities particularly on small water reservoirs. Higher suppression percentages should be expected on smaller agricultural reservoirs because daily operations are much simpler to perform. Although evaporation suppression is achievable on larger water supply reservoirs, better technology and materials need to be developed to increase efficiencies.

CHAPTER III

WATER RESOURCES OF TEXAS

Texas is one of the largest, most diverse, and fastest growing states in the nation. The state covers 268,596 square miles and has a population of 25.4 million people (TWDB 2012). The population is projected to grow 82% from 2010 to 2060 (TWDB 2012). Texas has 10 climatic regions. Water resources across the state include 3,700 named streams, 20 major aquifers, and 3,450 permitted reservoirs including 196 major reservoirs with controlled storage capacities of 5,000 acre-feet or more (TWDB 2012).

3.1 River Basins

Texas is divided into 15 major river basins and 8 coastal basins. The 23 river basins in Texas are listed in Table3.1 and illustrated in Figure 3.1. These basins are unique and vary in size, shape, climate, geology, topography, vegetation, and population. Seven of the major river basins are contained entirely within the state, and the other eight are interstate. The Rio Grande River and Canadian River Basin begin in Colorado; the Red River, Brazos River, and Colorado River Basins being in New Mexico. The Cypress Bayou and Sabine River Basins start in Texas but flow into Louisiana while the Sulphur River Basin flows into Arkansas. The remaining river basins spill into estuaries and bays along the coast.

Table 3.1 Texas River Basins

Map ID	River Basin	Basin Area Total (sq miles)	Basin Area in Texas (sq miles)
1	Brazos	45,573	42,865
2	Canadian	47,705	12,865
3	Colorado	42,318	39,428
4	Cypress	3,552	2,929
5	Guadalupe	5,953	5,953
6	San Antonio	4,180	4,180
7	Lavaca	2,309	2,309
8	Neches	9,937	9,937
9	Nueces	16,700	16,700
10	Red	93,450	24,297
11	Sabine	9,756	7,570
12	San Jacinto	3,936	3,936
13	Sulphur	3,767	3,580
14	Trinity	17,913	17,913
15	Rio Grande	182,215	49,387
	Coastal Basin		
16	Brazos-Colorado	1,850	1,850
17	Colorado-Lavaca	939	939
18	Lavaca-Guadalupe	998	998
19	Neches-Trinity	769	769
20	Nueces-Rio Grande	10,442	10,442
21	San Antonio-Nueces	2,652	2,652
22	San Jacinto-Brazos	1,440	1,440
23	Trinity-San Jacinto	247	247

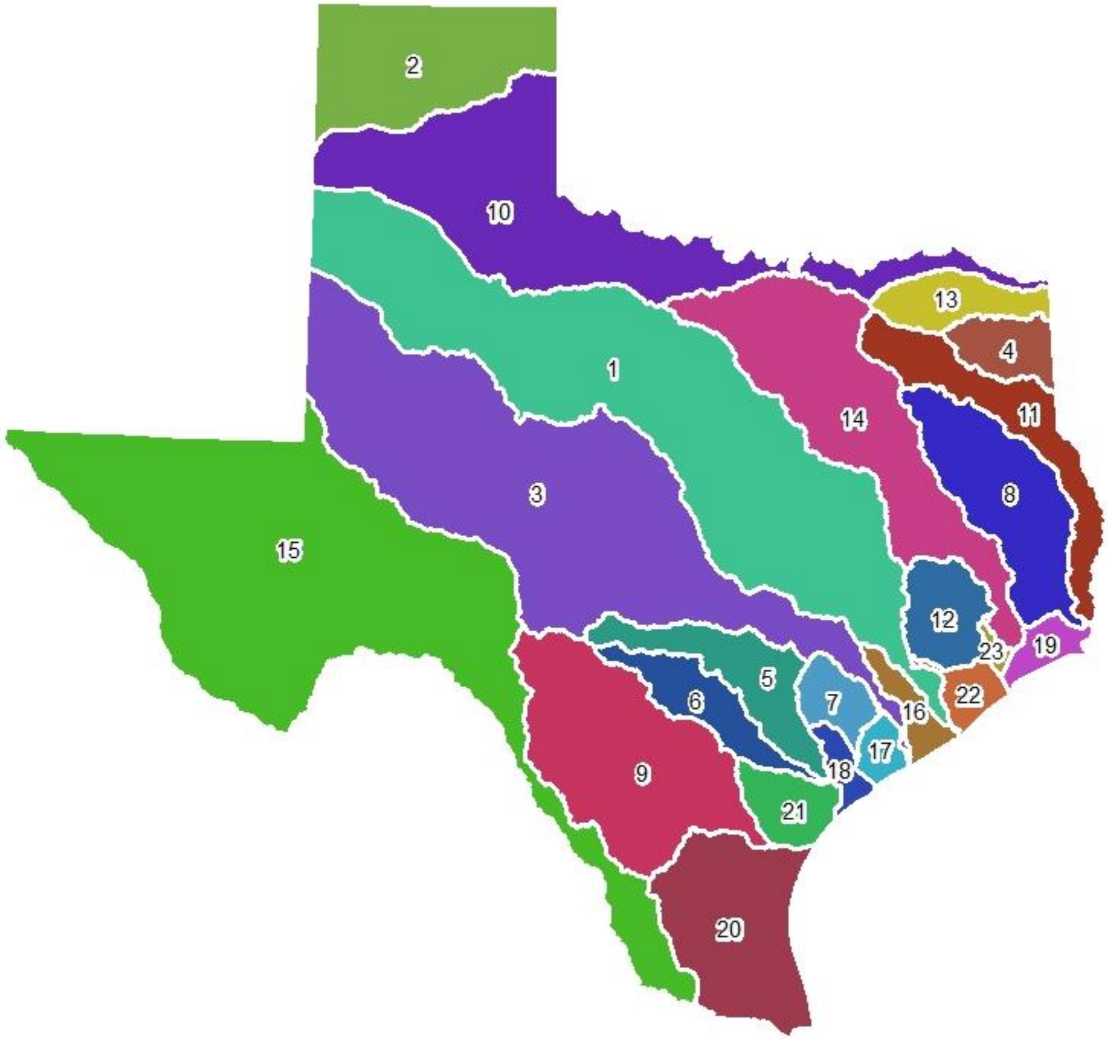

Figure 3.1 Texas River Basin Map (Wurbs 2011a)

Several of the river systems shown in Figure 3.2 are shared with neighboring states. The Rio Grande is shared with Mexico, the Red River is shared with Oklahoma, and the Sabine is shared with Louisiana. The interstate and international river basins, hydrology and water management in neighboring states and Mexico are considered to the extent necessary to assess water availability in Texas (Wurbs 2011a).

Figure 3.2 Major Rivers of Texas (Wurbs 2011a)

3.2 Texas Climate

Texas spans over 800 miles both north to south and east to west which causes large climatic variability. The variability is the result of several factors which includes the movements of seasonal air masses such as artic fronts from Canada, subtropical west winds from the Pacific Ocean and northern Mexico, tropical cyclones or hurricanes from the Gulf of Mexico, high pressure systems in the Atlantic Ocean, and jet stream movements (TWDB 2012). These interactions cause the western half of the state to have a semi-arid, continental type climate, and the remainder to have a humid, sub-tropical

Table 3.2 Texas Climate Region Descriptions (TWDB 2012)

Map ID	Climate Region	Climate Description
1	High Plains	Continental steppe or semi-arid savanna
2	Low Rolling Plains	Sub-tropical steppe or semi-arid savanna
3	North Central	Sub-tropical sub-humid mixed savanna and woodlands
4	East Texas	Sub-tropical humid mixed evergreendeciduous forestland
5	Trans-Pecos	Slightly wetter high desert mountainous areas, sub-tropical arid desert
6	Edwards Plateau	Sub-tropical steppe or semi-arid brushland and savanna
7	South Central	Sub-tropical sub-humid mixed prarie, savanna, and woodlands
8	Upper Coast	Sub-tropical humid marine prairies and marshes
9	Southern	Sub-tropical steppe or semi-arid brushland
10	Lower Valley	Sub-tropical sub-humid marine

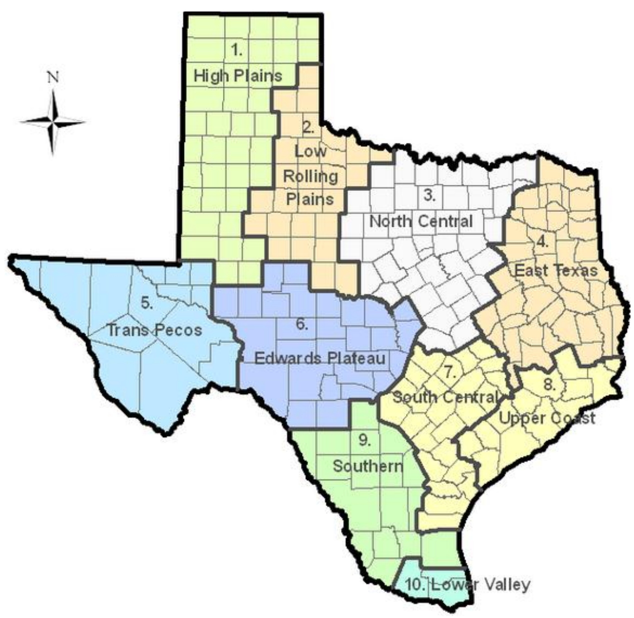

Figure 3.3 Texas Climate Region Map (TWDB 2012)

climate. The National Climatic Data Center has divided Texas into 10 climatological divisions in order to describe weather patterns across the state. The 10 climate divisions are described in Table 3.2 and illustrated in Figure 3.3.

Precipitation in Texas varies both geographically and temporally. Average annual precipitation decreases from over 55 inches in the east to less than 10 inches in the west. As seen in Figure 3.4, annual mean precipitation increase from west to east across the state on an average of about 1 inch for every 15 miles with little variation from north to south. The majority of precipitation is attributed to rain storms that produce a large amount of precipitation over a short period of time expect for the subtropical humid climate of the eastern quarter of the state (TWDB 2012). Following a similar pattern to rainfall, evaporation is less than 50 inches in East Texas and more than 75 inches per year in the Trans-Pecos region. Reservoir evaporation is shown in Figure 3.5. These weather patterns greatly impact the amount of water resources across the state. This typically includes naturalized streamflows, groundwater and surface water supplies.

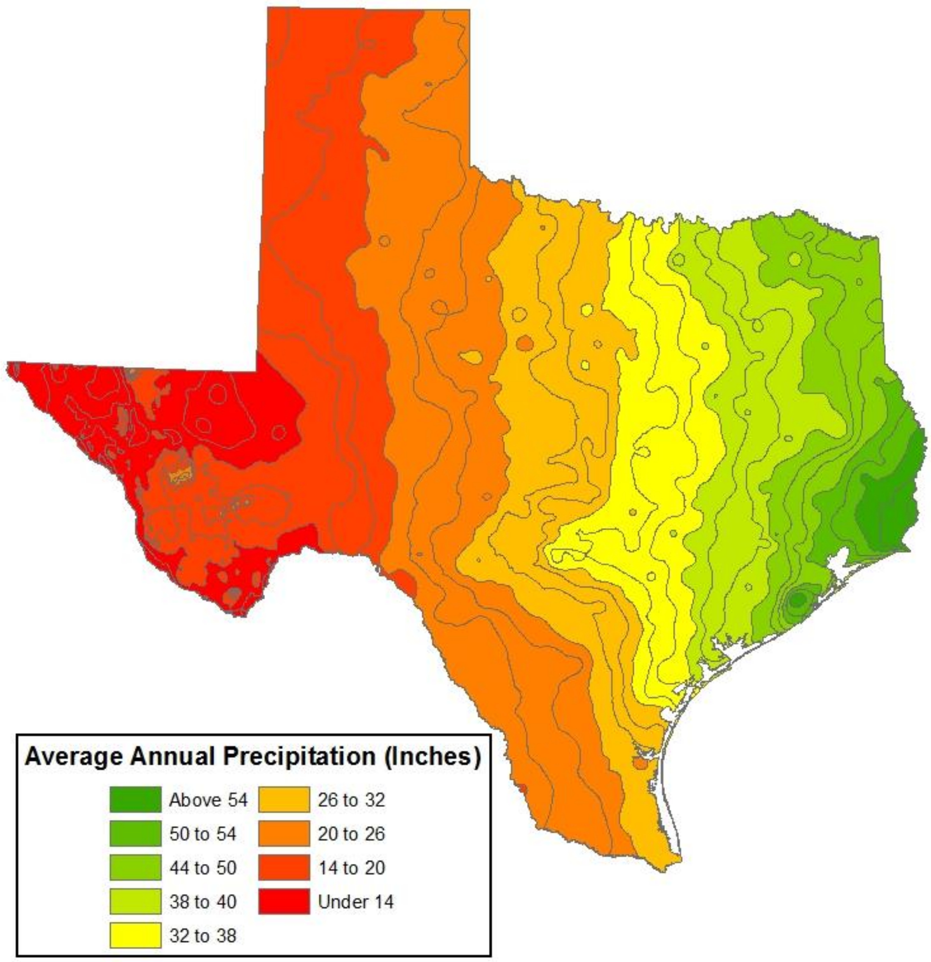

Figure 3.4 - Average Annual Precipitation (Inches)

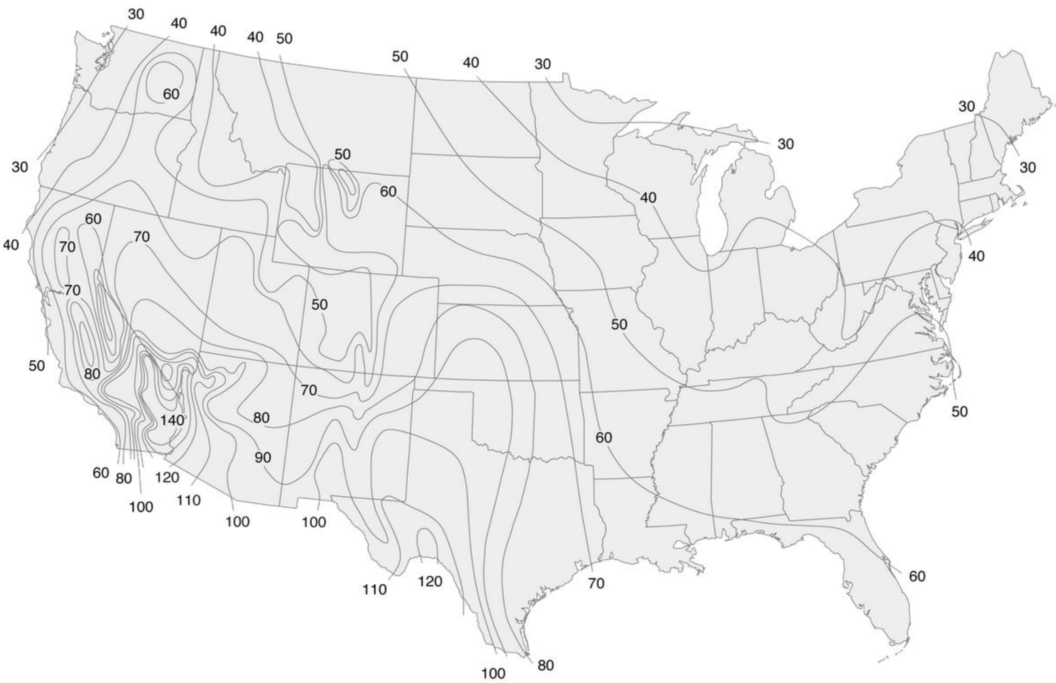

Figure 3.5 - United States Average Annual Potential Evaporation (inches/year) (Wurbs 2002)

3.3 Reservoirs

Texas has 3,450 reservoirs with 196 controlled storage capacities of 5,000 acre-feet or more (TWDB 2012). These major reservoirs represent over 95% of the total storage capacity in all Texas reservoirs and mainly serve as sources of flood control, water supply, and hydropower. The 30 largest reservoirs in Texas, listed in Table 3.3, each has a storage capacity of over 500,000 acre-feet and combined have a total capacity of 46.6 million acre-feet, which is 79% of the total capacity of the 196 major reservoirs. A breakdown of the distribution of reservoirs between various capacity ranges is shown in Table 3.4.

Table 3.3 - Reservoirs with Storage Capacities Greater Than 500,000 Acre-Feet

			Storage Capacity		
	Reservoir	River Basin	Conservation (acre-feet)	Flood Control (acre-feet)	Total
1	Lake Texoma	Red	2,643,300	2,669,000	5,312,300
2	Amistad, International Reservoir	Rio Grande	3,505,400	1,744,300	5,249,700
3	Toledo Bend Reservoir	Sabine	4,477,000	-	4,477,000
4	Sam Rayburn Reservoir	Neches	2,898,500	1,099,100	3,997,600
5	Falcon, International Reservoir	Rio Grande	2,767,400	513,300	3,280,700
6	Wright Patman Lake	Sulphur	145,300	2,363,700	2,509,000
7	Lake Travis	Colorado	1,172,600	781,400	1,954,000
8	Lake Livingston	Trinity	1,750,000	-	1,750,000
9	Lake Meredith	Canadian	920,300	462,200	1,382,500
10	Lake Whitney	Brazos	627,100	745,300	1,372,400
11	Richland-Chambers Reservoir	Trinity	1,181,866	-	1,181,866
12	Belton Lake	Brazos	457,600	640,000	1,097,600
13	Lake Ray Roberts	Trinity	799,600	265,000	1,064,600
14	Lewisville Lake	Trinity	640,986	340,814	981,800
15	Lake Tawakoni	Sabine	927,440	-	927,440
16	Lake Buchanan	Colorado	922,000	-	922,000
17	Lake O' the Pines	Cypress	254,900	587,200	842,100
18	Lavon Lake	Trinity	456,500	291,700	748,200
19	Canyon Lake	Guadalupe	386,200	354,700	740,900
20	Possum Kingdom Lake	Brazos	504,100	220,639	724,739
21	Choke Canyon Reservoir	Nueces	689,314	-	689,314
22	Cedar Creek Reservoir Trinity	Trinity	679,200	-	679,200
23	Cedar Creek Reservoir Colorado	Colorado	679,200	-	679,200
24	Fork Reservoir, Lake	Sabine	675,819	-	675,819
25	Twin Buttes Reservoir	Colorado	186,200	454,400	640,600
26	Stillhouse Hollow Lake	Brazos	235,700	394,700	630,400
27	O.H. Ivie Reservoir	Colorado	554,339	-	554,339
28	Lake Waco	Brazos	169,200	384,100	553,300
29	Somerville Lake	Brazos	160,100	347,400	507,500
30	Lake Kemp	Red	268,000	234,900	502,900
Total			31,735,164	14,893,853	46,629,017

Table 3.4 - Reservoir Capacity Ranges

Total Controlled Capacity (Acre-Feet)	Number of Reservoirs
5,000 - 50,000	115
50,000 - 100,000	11
100,000 - 500,000	40
500,000 - 1,000,000	17
1,000,000 - 2,000,000	7
2,000,000 - 5,000,000	4
over 5,000,000	2
Total	196

A majority of reservoir construction in Texas took place between 1935 and 1970. During this time the number of major reservoirs rose from 35 to 162. These reservoirs were developed and are managed by a variety of federal, state and local government agencies, and private companies. This includes The United States Army Corps of Engineers, the United States Bureau of Reclamation, the International Boundary and Water Commission, the National Resource Conservation Service, state water districts and river authorities, municipalities, private companies, and the Texas Department of Water Resources. In addition Texas participates in 5 interstate river compacts with Colorado, New Mexico, Oklahoma, Louisiana, and Arkansas.

Reservoir storage capacity is usually divided into 4 pools. The dead or inactive pool is the part of a reservoir that is below the lowest outlet, which means water cannot be released through gravity methods. This area is usually full of sediment deposits. The conservation pool is the elevation that water is normally at in reservoirs. It is typically the maximum operating level for reservoirs. The next part of the reservoir is referred to as the flood control pool. This is made up of the uncontrolled (no gate) storage and controlled (gate) storage. Controlled storage areas are regulated by gates, valves, or pumps. The area above the flood control pool is known as the surcharge pool (temporary flood pool) and is typically used to pass predicted floods through the reservoir. The four general reservoir pools are shown in Figure 3.6. Reservoir storage capacity along with instream flow, evaporation and other losses impact water supply firm yield. Firm yield is the maximum quantity of water which can be supplied from a reservoir annually through an extended drought period, which is typically taken to be the historical period of lowest natural flow on record for the stream (Wurbs and Bergman 1990).

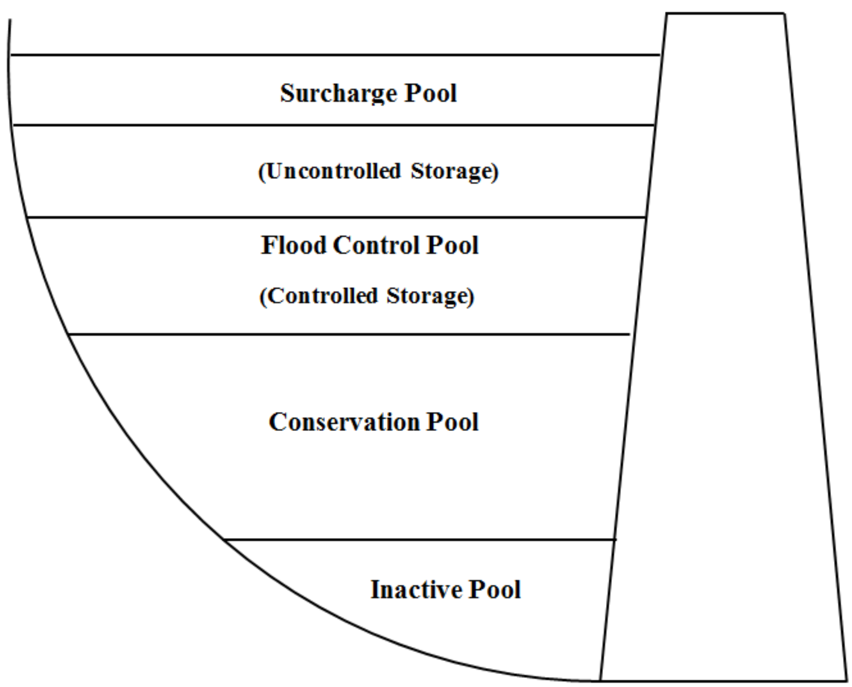

Figure 3.6 - Reservoir Storage Pools

3.4 Water Supply Needs

Current water supplies in Texas are mainly provided by surface water and groundwater sources; however, water reuse and seawater desalination are expected to become a growing source of water over the next 50 years (TWDB 2012). According to Water for Texas 2012 State Water Plan (2012), the state's existing water supplies are projected to decrease about 10% over the next 50 years, from about 17.0 million acre-feet in 2010 to about 15.3 million acre-feet in 2060.

Surface water supplies close to 40% of the water used in Texas, while groundwater accounts for nearly 60%. Surface water is provided by the major water supply reservoirs located in the state's river basins. As of 2010, total existing surface water supplies were estimated at 8.5 million acre-feet. Table 3.5 provides a breakdown of existing surface water supplies on a river basin basis from 2010 to 2060. The increase in water supply is contributed to additional water made available through existing contracts and the decrease is attributed to the increase in reservoir sedimentation.

Table 3.5 - Existing Surface Water Supplies by River Basin (Acre-Feet/Year) (TWDB 2012)

River Basin	2010	2020	2030	2040	2050	2060	Percent Change
Brazos	1,273,273	1,271,586	1,275,209	1,277,160	1,277,876	1,278,589	0
Brazos-Colorado	21,433	21,485	21,536	21,591	21,654	21,662	1
Canadian	44,174	55,816	55,779	55,729	54,332	54,264	22
Colorado	994,305	989,650	990,151	991,147	992,524	991,281	0
Colorado-Lavaca	4,298	4,298	4,298	4,298	4,298	4,298	0
Cypress	274,271	273,979	273,618	273,247	273,915	274,029	0
Guadalupe	205,990	206,626	205,197	201,260	201,329	201,408	-2
Lavaca	79,354	79,354	79,354	79,354	79,354	79,354	0
Lavaca-Guadalupe	434	434	434	434	434	434	0
Neches	524,063	802,883	985,391	1,013,133	1,034,174	1,060,852	102
Neches-Trinity	79,066	79,066	79,066	79,066	79,066	79,067	0
Nueces	148,874	153,069	157,631	159,427	159,934	160,746	8
Nueces-Rio Grande	8,908	8,908	8,908	8,908	8,908	8,908	0
Red	342,559	328,060	323,901	319,524	314,769	309,339	-9
Rio Grande	1,150,631	1,144,214	1,138,329	1,132,278	1,125,801	1,119,901	-2
Sabine	691,243	670,275	650,091	649,761	649,841	648,341	-6
Sabine-Louisiana	235	235	235	235	235	235	0
San Antonio	61,259	61,259	61,258	61,258	61,257	61,256	0
San Antono-Nueces	1,794	1,794	1,794	1,794	1,794	1,794	0
San Jacinto	202,592	202,952	203,117	203,113	203,126	203,133	0
San Jacinto-Brazos	27,450	27,434	27,501	27,545	27,597	27,645	0
Sulphur	308,788	311,559	316,552	321,336	325,577	333,513	8
Trinity	1,943,370	1,962,750	1,970,841	1,993,645	2,021,370	2,009,621	3
Trinity-San Jacinto	39,068	39,069	39,071	39,022	38,952	38,871	0
Total	**8,427,432**	**8,696,755**	**8,869,262**	**8,914,265**	**8,958,117**	**8,968,541**	**6**

Current estimates place total surface water availability in Texas at 13.5 million acre-feet per year and predict it will decrease to 13.3 million acre-feet per year by 2060 (TWDB 2012). A breakdown of surface water availability by river basin is provided in Table 3.6.

Table 3.6 – Surface Water Availability by River Basin (Acre-Feet/Year) (TWDB 2012)

River Basin	2010	2020	2030	2040	2050	2060	Percent Change
Brazos	1,641,169	1,653,791	1,594,374	1,586,831	1,579,328	1,571,832	-4
Brazos-Colorado	21,433	21,485	21,536	21,591	21,654	21,662	1
Canadian	48,136	68,105	68,064	68,024	67,984	67,947	41
Colorado	1,170,052	1,149,068	1,154,169	1,183,249	1,189,432	1,225,451	5
Colorado-Lavaca	4,298	4,298	4,298	4,298	4,298	4,298	0
Cypress	378,087	377,847	377,607	377,367	377,127	376,887	0
Guadalupe	273,961	273,890	273,820	273,749	273,678	273,607	0
Lavaca	79,374	79,374	79,374	79,374	79,374	79,374	0
Lavaca-Guadalupe	434	434	434	434	434	434	0
Neches	2,328,154	2,324,792	2,321,431	2,318,067	2,314,705	2,311,367	-1
Neches-Trinity	79,070	79,070	79,070	79,070	79,070	79,071	0
Nueces	185,920	184,902	183,884	182,866	181,851	180,843	-3
Nueces-Rio Grande	8,922	8,922	8,922	8,922	8,922	8,922	0
Red	578,732	574,363	569,966	565,463	560,798	556,427	-4
Rio Grande	1,184,415	1,176,889	1,169,864	1,162,838	1,155,812	1,149,286	-3
Sabine	1,837,834	1,834,362	1,830,796	1,827,234	1,823,675	1,820,110	-1
Sabine-Louisiana	235	235	235	235	235	235	0
San Antonio	61,259	61,259	61,258	61,258	61,257	61,256	0
San Antono-Nueces	1,794	1,794	1,794	1,794	1,794	1,794	0
San Jacinto	324,110	320,570	316,835	312,931	309,044	305,151	-6
San Jacinto-Brazos	58,791	58,775	51,026	51,070	51,122	51,170	-13
Sulphur	524,561	522,307	519,889	517,755	515,332	513,224	-2
Trinity	2,708,894	2,571,944	2,540,440	2,561,796	2,604,123	2,596,498	-4
Trinity-San Jacinto	39,156	39,157	39,159	39,160	39,161	39,179	0
Total	**13,538,791**	**13,387,633**	**13,268,245**	**13,285,376**	**13,300,210**	**13,296,025**	**-2**

Rapid population growth and the possibility of extreme drought, greatly increase the amount of water needed in the future. According to the 2012 State Water Plan, an additional water supply of 3.6 million acre-feet was needed in 2010 and 8.3 million acre-feet by 2060. In order to meet additional water supply needs the 2011 regional water plans recommends the development of 26 major reservoirs by 2060, providing 1.5 million acre-feet of water annually. The recommend sites are in areas of the state that are projected to have high population and economic growth. Figure 3.7 depicts the location of the recommend reservoirs. Evaporation suppression studies will help evaluate the additional amount of water volume that can be supplied in each basin at various percentage reductions in evaporation rates.

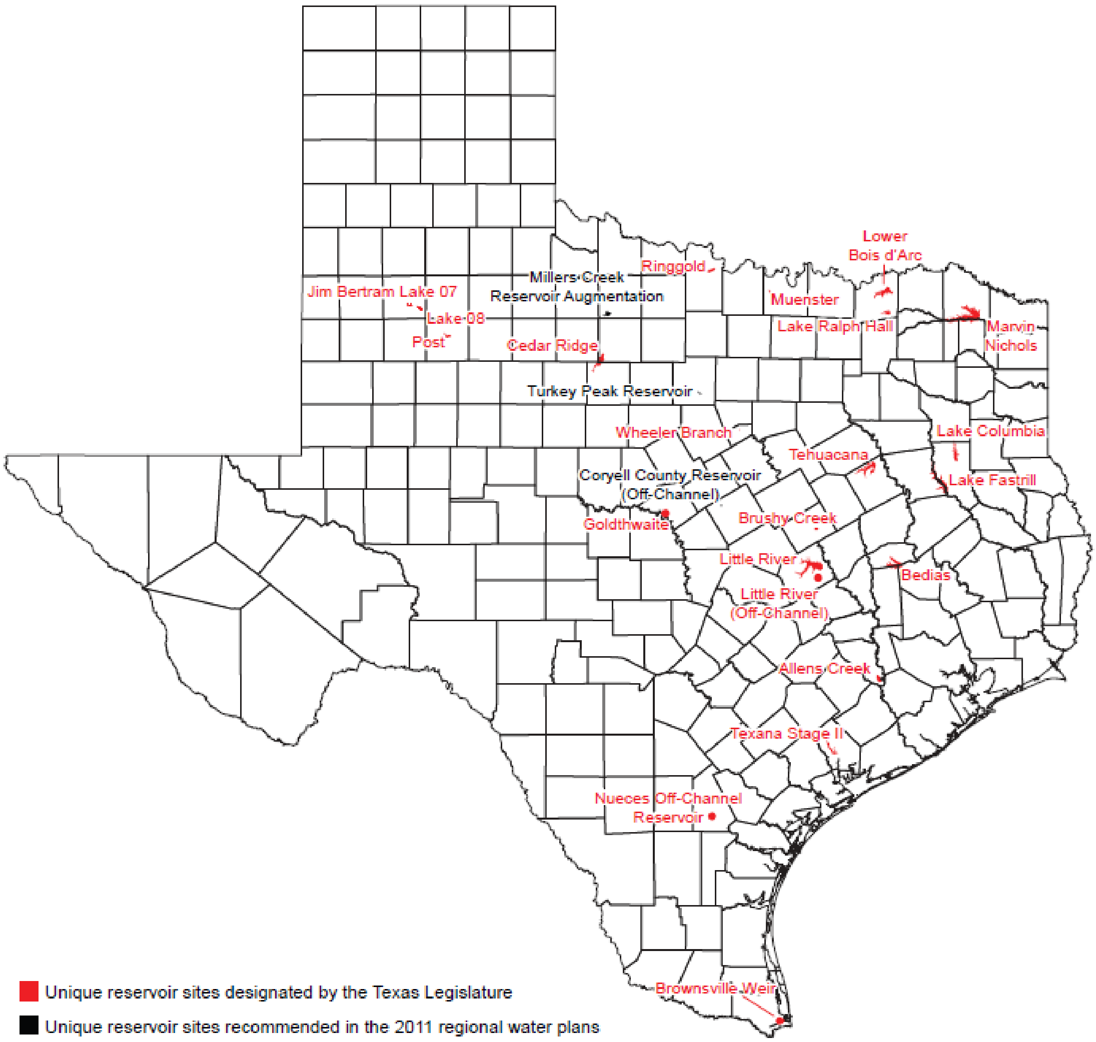

Figure 3.7 – Designated and Recommended Unique Reservoir Sites (TWDB 2012)

CHAPTER IV

WRAP SIMULATION MODEL

The version of the WRAP simulation model used in this study was modified to compute reservoir evaporation and precipitation volumes independently of one another rather than computing net evaporation less precipitation volumes. These changes allow for evaporation suppression analyses to be performed as well as quantification of evaporation volumes. Additional input data regarding precipitation and lake evaporation is required for reservoirs in the dataset. This data was obtained from the Texas Water Development Board datasets described in Chapter I.

4.1 Simulation Overview

The modified version of the WRAP simulation model SIM developed for this study is called SIME. The SIME program is based on computation routines used in WRAP-SIM but the methods used to compute reservoir evaporation and precipitation volumes were modified. These modifications allow for the independent computation of reservoir evaporation and precipitation volumes. The basic WAM input datasets developed for the river basins in Texas were used to performing WRAP-SIME simulations, including the DAT, FLO, and DIS files. Two additional file, Precipitation.PPP and Evaporation.EEE replace the EVA file in the SIME input datasets. These two files contain the statewide TWDB evaporation and precipitation datasets.

The DAT input includes required and optional records for controlling various simulation options and represents the river/reservoir/rights system being modeled (Wurbs 2011b). In order to enable SIME evaporation suppression analysis capabilities, a few modifications were made to the DAT input file. Two new fields, 13 and 14, were added to the *JD* record. The *J*ob control *D*ata record specifies general information for controlling the simulation including the hydrologic period-of-analysis and parameters for several *SIM* computational features including options associated with negative incremental flows, system reservoir release decisions, beginning-ending storage, priority system, input and output, and error checking (Wurbs 2011b). Field 13 allows the user to specify at what fraction of reservoir storage capacity evaporation suppression will be applied while field 14 is used to set the amount that the water surface evaporation rate will be reduced. Table 4.1 provides an explanation of the proper format used to specify the two new inputs

Table 4.1 JD Record – Simulation Job Control Data

field	columns	variable	format	value	description
					Default for Evaporation-Precipitation Adjustment
10	72	EPADJ	I8	blank,0	No adjustment unless specified on *CP* record
				–1	Adjustments based on ungaged CP (*FD* field 2)
				–2	Adjustments based on gaged CP (*FD* record field 3)
					Dimension Limit for IS/IP, SV/SA, PV/PE, and TQ/TE Records
11	80	TL	I8	Blank, ≤12	Default maximum limit = 12 pairs of values in tables.
				≥13	Maximum limit on number of entries in tables.
					Alternate Water Right Identifiers in WR Record Fields 12-14 and 15-17
12	88	IDSET	I8	blank,0,1	First set of identifiers on *WR* input records are used.
				2	Second set of identifiers on *WR* records are used.

New fields added to the *JD* record provide defaults for EX(cp,5) and EX(cp,6) on *EX* records.

field	columns	variable	format	value	description
13	89-96	EX5	F8.0	+	Default for storage level EX(cp,5) on *EX* records.
				blank, 0	Default = 1.0
14	97-104	EX6	F8.0	+	Default for reduction factor EX(cp,6) on *EX* records.
				blank, 0	Default = 0.0

EX records were also added to the DAT file. Each EX record represents a weighted average of the net reservoir evaporation associated with quadrangles for a given CP record. EX records are specified directly after its CP record in the DAT file. The number of EX records varies for each river basin but should be equal to the set of EV records found in the EVA file. For example, the Brazos WAM with a 1940-1997

(58 years) period-of-analysis contains data for 67 control points in the EVA file and 67x58 = 3,886 EV records. Therefore the Brazos should have 67 EX records. Table 4.2 provides an explanation to the proper format of EX records.

Table 4.2 EX Record Evaporation Factors

field	columns	variable	format	value	description
1	1-2	CD	A2	EX	Record identifier
2	3-8	EX(cp,5)	F6.0	+	Reduction trigger as fraction of storage capacity.
3	9-16	EX(cp,6)	F8.0	+	Evaporation reduction fraction.
4	17-24	EXQ(cp,1)	I8	+	Evaporation quadrangle identifier.
5	25-32	EX(cp,1)	F8.0	+	Weighting factor. Default = 1.0
6	33-40	EXQ(cp,2)	I8	+	Evaporation quadrangle identifier.
7	41-48	EX(cp,2)	F8.0	+	Weighting factor. Default = 0.0
8	49-56	EXQ(cp,3)	I8	+	Evaporation quadrangle identifier.
9	57-64	EX(cp,3)	F8.0	+	Weighting factor. Default = 0.0
10	65-72	EXQ(cp,4)	I8	+	Evaporation quadrangle identifier.
11	73-80	EX(cp,4)	F8.0	+	Weighting factor. Default = 0.0

Fields 5, 7, 9, and 11 are weighted quadrangle coefficients between 0.0 and 1.0 that sum to 1.0. These quadrangle coefficients were determined based on a ratio of the inverse of the distance squared from the reservoir centroids to the quadrangle centroids (Brown & Root Services 2001). Based upon these coefficients, a weighted average of the evaporation-precipitation associated with quadrangles EXQ(cp,1), EXQ(cp,2), EXQ(cp,3), and EXQ(cp,4) is computed. Depending on the size of the reservoir the number of quadrangles can range between one and four. Previous studies performed by HDR, R.J. Brandes Company, Brown and Root, and Espey Consultants have developed reservoir evaporation-precipitation equations for the Brazos, Colorado, Red, Canadian, Sabine, and Trinity River Basins. A sample equation is provided below where the monthly evaporation depth in inches for Lake Buchanan is a weighted average of the evaporation depths for quadrangles 609, 709, and 710.

Lake Buchanan evaporation depth = 0.283(609) + 0.692(709) + 0.025(710)

Equations used for evaporation suppressions analysis can be found in Appendix A.

The original FLO and DIS are used by SIME. Naturalized streamflow are entered on series of inflow IN records or computed from naturalized flows entered on IN records at one or more other control points (Wurbs, 2011b). The DIS file contains all information about flow distributions throughout the reservoir. Fields in the file contain specifications for transferring flows from gaged to ungagged sites, flow distribution coefficients for certain flow distribution options, and watershed parameters used in flow distribution computations.

The last two datasets required to perform evaporation suppression analyses using SIME are Precipition.PPP and Evaporation.EEE. The files contain the statewide TWDB datasets of historical monthly and annual precipitation and lake evaporation for each one-degree quadrangle in and adjacent to Texas maintained by the Texas Water Development Board as described in Chapter I.

4.2 Reservoir Evaporation Computations

SIME mean reservoir evaporation volume computation routines are similar to net evaporation-precipitation computation routines performed in SIM. In SIM, net evaporation less precipitation volumes are computed by multiplying the reservoir water surface area by net evaporation-precipitation rates provided on *EV* records in dimensions of depth/month (Wurbs 2011a). However in SIME, the reservoir water surface area is multiplied by evaporation and precipitation rates separately, thus allowing for individual computation. The computation of evaporation and precipitation volumes are incorporated in *HYD* and *SIM* reservoir volume accounting routines (Wurbs 2011a).

Reservoir volume accounting routines require several iterative water budget computations performed within *SIM* for each individual water right that has reservoir storage (Wurbs 2011a). Reservoir surface area, which is just a simple average of the areas at the beginning and end of the month, are determined through reservoir volume relationships. Typically, storage volume versus surface area tables are provided on *SV/SA* record for major reservoirs the confidents on the *WS* record. The beginning-of-month area is determined as a function of the known beginning-of-month storage volume (Wurbs 2011a). By default, all reservoirs are assumed to be full to their maximum storage capacity at the beginning of the simulation (Wurbs 2011a). However, the unknown end-of-month reservoir storage volume depends upon the net evaporation volume. Thus, the estimated end-of-month reservoir surface changes during the course of iterative computations along with the improvements in the end-of-month storage volume and net evaporation volume estimates.

The end-of-month storage volume is dependent on a number of factors such as stream flow depletions, releases from upstream system reservoirs, diversions and releases from reservoirs, and return flows. The stopping criterion for the iterative algorithm is based on comparing successive computed end-of-month storage volumes (Wurbs 2011a). The computations stop if the difference between successive end-of-month storage volumes is less than either 0.1 acre-foot or 0.01 percent. Computation also stops upon completion of a maximum of 50 iterations (Wurbs 2011a).

The following previously-computed known amounts are provide to the *SIM* routine that performs the iterative computations to determine reservoir outflow, net evaporation, and end-of-month storage volumes for a particular reservoir for a particular water right (Wurbs, 2011a).

- Beginning-of-month storage
- Stream inflows into the reservoir from stream flow depletions for senior rights
- Inflows into the reservoir from releases from upstream reservoirs for senior rights
- Available stream flow still remaining for appropriation by the current water right
- Outflows (releases and diversions) for other more senior water rights

- Outflow target for the current water right

4.3 Differences in WRAP-SIM and WRAP-SIME Evaporation and Precipitation Depths

The evaporation and precipitation depths used in the SIME simulations of this study are consistently from the statewide TWDB datasets described in Chapter I, stored in the two files with filenames Evaporation.EEE and Precipitation.PPP. The net evaporation-precipitation rates in the EVA files of the original TCEQ WAM System datasets were developed largely from the same TWDB database. However, for some of the larger reservoirs, pan evaporation measurements and gaged precipitation at the reservoir sites were adopted rather the TWDB data which is aggregated by quadrangle.

Filling in of missing data was also handled differently in this study versus during development of the original WAM datasets in some cases. Months of missing data occur primarily in quadrangles that overly the boundaries of Texas, either boundaries with Mexico or other states or the Gulf of Mexico.

CHAPTER V

EVAPORATION SUPPRESSION SIMULATION RESULTS

In order to quantify the impact of reservoir evaporation on water supply availability and reliability, simulations were performed using modified TCEQ WAM system input datasets and the recently developed WRAP-SIME program. The simulation study included river/reservoir system water budgets and water supply reliabilities with and without evaporation suppression.

A variety of WRAP simulations were performed for 19 out of the 21 Texas WAM system river basins. Simulations were not performed for the Lavaca-Guadalupe Coastal River Basin because there are no reservoirs in the dataset. Individual reservoir evaporation suppression studies were performed for Amistad, Falcon and Red Bluff in the Rio Grande River Basin. Basin wide simulations were not conducted for the Rio Grande River Basin because limited evaporation and precipitation data is available for Mexico and New Mexico. Additional analyses were also performed on Lake Hubbard Creek and Proctor in order to gain a better understanding of how individual reservoir's water supply availability/reliability capabilities respond to evaporation suppression.

Simulations were performed using WRAP-SIME and the modified input dataset described in Chapter IV. Base simulations were performed at 100% of the reservoir storage capacity with 0% evaporation suppression. This provides information on current water supply conditions in each of the 19 river basin for which analyses were performed. Table 5.1 illustrates the combinations of reservoir storage capacities and evaporation suppression percentages that were analyzed. Detailed simulation results including a volume budget for each river basin, water supply diversions, shortages, and reliabilities, reservoir storage capacities, and reservoir storage frequency tables can be found in Appendix B.

Table 5.1 – River Basin Evaporation Suppression Simulation Study Combinations

Simulation	Storage Capacity Trigger	Evaporation Suppression
1	100%	0%
2	100%	10%
3	100%	25%
4	100%	100%
5	75%	0%
6	75%	10%
7	75%	25%
8	75%	100%
9	50%	0%
10	50%	10%
11	50%	25%
12	50%	100%
13	25%	0%
14	25%	10%
15	25%	25%
16	25%	100%

5.1 TCEQ WAM System Authorized Use Datasets

The TCEQ WAM system has two sets of input files, Full Authorized Use and Current Condition Use, for each of the river basins. All evaporation suppression studies were performed using the Full Authorized Use dataset. This dataset was selected because the full amounts authorized by permits are used when performing the simulation. Since only permanent water rights are included in the Full Authorized dataset, it is used by TCEQ to evaluate new permanent water right applications. Additionally, full reuse with no return flows are assumed. These conditions provide a worst case scenario condition for evaluating water supply availability/reliability on a basin by basin basis. Information found in the Authorized Uses dataset include period of analysis, number of primary and total control points, number of water rights (WR), number of instream flow (IF) records, and number of reservoirs for each of the 21 WAM river basins are listed in Table 5.2.

As seen in Table 5.2 there is great diversity between each of the 23 Texas river basins modeled by the 21 datasets. Texas is unique in the sense that there are a large number of reservoirs across the state and each greatly vary in size. Some river basin such as the Sabine River Basin have several reservoirs with large storage capacities while others like the San Antonio-Nueces River Basin, do not. As seen in Figure 5.1 each of the river basins varies in size. Some of the larger river basins, Red, Brazos, Colorado, and Rio Grande have very large drainage areas and span much of the state.

Table 5.2 – Texas WAM System Model Datasets

Map ID	Major River Basin or Coastal Basin	Period of Analysis	Number of Primary Control Points	Number of Total Control Points	Number of WR Record Rights	Number of IF Record Rights	Number of Model Reser-voirs	Reservoir Storage Capacity (acre-feet)	WAM File Name
			Major River Basins						
1	Canadian River Basin	1948-98	12	85	56	0	47	966,000	CRUN3
2	Red River Basin	1948-98	47	447	494	101	245	4,124,000	red3
3	Sulphur River Basin	1940-96	8	83	85	10	57	753,000	sulphur3
4	Cypress Bayou Basin	1948-98	10	147	163	1	91	902,000	cyp3
5	Rio Grande Basin	1940-00	55	957	2,584	4	113	23,918,000	RG3
6	Colorado River Basin and Brazos-Colorado Coastal	1940-98	45	2,395	1,922	86	511	4,763,000	C3
7	Brazos River Basin and San Jacinto-Brazos Coastal	1940-97	77	3,842	1,634	122	678	4,695,000	Bwam3
8	Trinity River Basin	1940-96	40	1,343	1,027	35	700	7,504,000	Trin3
9	Neches River Basin	1940-96	20	306	328	19	180	3,904,000	Neches3
10	Sabine River Basin	1940-98	27	376	310	21	207	6,401,000	Sabine3
11	Nueces River Basin	1934-96	41	542	373	30	121	1,040,000	N_RUN3
12	Guadalupe San Antonio River	1934-89	46	1,338	848	200	238	808,000	gsa_run3
13	Lavaca River Basin	1940-96	7	185	72	30	22	235,000	lav3
14	San Jacinto River Basin	1940-96	17	412	150	15	114	637,000	sjarun3
			Coastal Basin						
15	Lower Nueces-Rio Grande	1948-98	16	119	70	6	42	101,700	LowerNrg3
16	Upper Nueces-Rio Grande	1948-98	13	81	34	2	22	11,000	UpperNRG3
17	San Antonio-Nueces	1948-98	9	53	12	2	9	1,480	SAN_R3
18	Lavaca-Guadalupe Coastal	1940-96	2	68	10	0	0	0	lavgua3
19	Colorado-Lavaca Coastal	1940-96	1	111	27	4	8	7,230	col-lav3
20	Trinity-San Jacinto Coastal	1940-96	2	94	24	0	13	4,880	TSJ3
21	Neches-Trinity Coastal	1940-96	4	245	138	9	31	58,000	NT3
	Total		499	13,229	10,361	697	3,449	60,834,290	

These basins have large amounts of climate variability and water use consumption. Therefore, evaporation suppression simulations results help provide insight on the sensitivity of water supply availability/reliability to climatic conditions and water use demand changes.

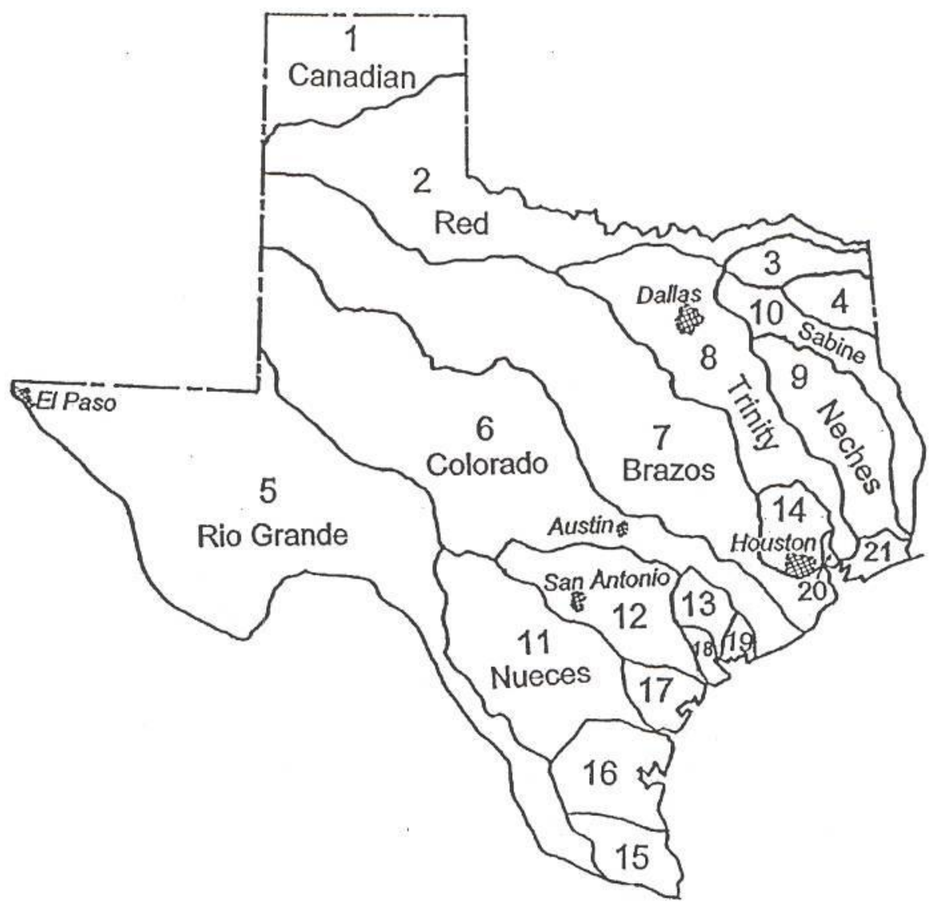

Figure 5.1 - WAM System River Basins

5.2 River Basin Summaries

In order to quantify current hydrology conditions in each of the 19 river basins, simulations were performed using WRAP-SIM and WRAP-SIME. River basin summary results can be found in Table 5.3 while individual reservoir results are provided in Table 5.4. Base simulations help provide an understanding of current river basin conditions.

A variety of river basin information is included in Table 5.3 and Table 5.4 This includes the number of reservoirs, basin mean storage capacity, basin mean storage, net evaporation-precipitation, naturalized flows, unappropriated flows, diversion targets, actual diversions, diversion shortages, and volume reliabilities. Results reported in Table 5.3 are not representative of individual reservoirs but aggregate river basin conditions. Storage capacities are specified in *W*ater *S*torage records and define the pool from which water rights can be diverted from and the total cumulative capacity to which reservoirs can be refilled under the priority of water rights for use in future months. Naturalized streamflows are flows that would have occurred naturally without specified water uses or reservoirs. Unappropriated flows represent water that is still available to meet additional appropriated flows in the model. Diversion targets, actual diversions, and diversion shortages all relate to water rights in each of the TCEQ WAM river basins. Diversion targets represent the total annual diversion amount from all *W*ater *R*ight records in the DAT file for a particular river basin.

Table 5.3 – River Basin Summaries

river basin	Canadian	Red	Sulphur	Cypress	Colorado	Brazos
map number	1	2	3	4	6	7
Information from Original TCEQ WAM System						
number of reservoirs	47	245	57	91	511	678
storage capacity (acre-feet)	965,338	4,008,825	757,105	878,903	5,190,238	4,648,234
mean storage (ac-ft)	537,193	3,261,075	608,074	657,243	2,999,652	3,512,163
evaporation-prec (ac-ft/yr)	52,080	274,014	54,726	45,345	185,464	397,445
naturalized flow (ac-ft/yr)	190,402	3,112,338	2,498,278	1,675,736	2,753,668	7,735,887
unappropriated (ac-ft/yr)	161,739	1,926,756	2,069,807	1,257,359	119,999,992	5,536,106
diversion targets (ac-ft/yr)	165,195	1,162,720	380,549	1,184,050	405,195,392	2,452,796
diversions (acre-feet/year)	118,876	1,026,704	375,464	673,223	74,760,296	2,207,648
shortage (acre-feet/year)	46,318	136,016	5,085	510,827	330,435,008	245,149
reliability (percentage)	71.96%	88.30%	98.66%	56.86%	18.45%	90.01%
Additional Information Associated with Separating Evaporation and Precipitation						
evap-precip (ac-ft/year)	50,376	213,492	-444	744	168,173	339,007
evaporation (ac-ft/year)	73,267	616,551	218,858	189,720	371,403	817,336
precipitation (ac-ft/year)	22,891	403,041	219,301	188,976	203,241	478,431
evap-precip (inches/year)	44.53	19.60	-0.10	0.19	26.14	23.51
evaporation (inches/year)	20.24	56.61	48.61	47.58	57.73	56.68
precipitation (inches/year)	13,574.60	37.00	48.71	47.40	31.59	33.18
surface area (acres)	13,575	130,702	54,027	47,845	77,198	173,030
mean storage (acre-feet)	966,248	3,317,959	614,168	674,058	3,019,175	3,524,674

Table 5.3 Continued

river basin map number	Trinity 8	Neches 9	Sabine 10	Nueces 11	Guadalupe San Antonio 12	Lavaca 13
Information from Original TCEQ WAM System						
number of reservoirs	700	180	212	121	238	22
storage capacity (acre-feet)	7,340,382	3,903,814	6,403,082	1,037,890	805,561	234,778
mean storage (ac-ft)	5,076,262	3,337,944	5,575,516	272,813	574,818	203,605
evaporation-prec (ac-ft/yr)	455,460	127,460	169,493	52,849	59,848	30,344
naturalized flow (ac-ft/yr)	6,886,258	6,234,721	6,882,899	872,471	2,127,941	942,920
unappropriated (ac-ft/yr)	3,275,751	4,458,442	2,165,450	11,974,889	118,794,528	781,388
diversion targets (ac-ft/yr)	8,145,170	1,977,157	2,613,427	853,213	8,877,536	317,951
diversions (acre-feet/year)	5,820,081	1,724,246	2,580,915	668,685	6,404,522	164,565
shortage (acre-feet/year)	2,325,088	253,010	32,513	184,528	2,473,013	153,386
reliability (percentage)	71.45%	87.21%	98.76%	78.37%	72.14%	51.76%
Additional Information Associated with Separating Evaporation and Precipitation						
evap-precip (ac-ft/year)	251,366	-24,800	-53,277	43,223	37,430	11,722
evaporation (ac-ft/year)	1,188,914	648,868	1,001,309	93,695	90,653	59,317
precipitation (ac-ft/year)	937,549	673,660	1,054,558	50,471	53,222	47,594
evap-precip (inches/year)	11.34	-1.79	-2.57	25.57	22.78	9.90
evaporation (inches/year)	53.63	46.83	48.26	55.44	55.18	50.11
precipitation (inches/year)	42.29	48.62	50.83	29.86	32.39	40.20
surface area (acres)	266,030	166,259	248,985	20,281	19,716	14,206
mean storage (acre-feet)	5,134,371	3,390,582	5,698,497	273,915	585,094	207,342

Table 5.3 Continued

river basin	San Jacinto	Lower Nueces-RG	Upper Nueces-RG	SA Nueces	Colorado Lavaca	Trinity San Jacinto	Neches Trinity
map number	14	15	16	17	19	20	21
Information from Original TCEQ WAM System							
number of reservoirs	114	42	22	9	8	13	31
storage capacity (acre-feet)	633,149	101,580	10,496	1,462	7,212	4,849	57,985
mean storage (ac-ft)	507,642	29,533	5,783	1,119	5,410	2,347	32,025
evaporation-prec (ac-ft/yr)	34,272	8,296	1,711	529	673	391	2,715
naturalized flow (ac-ft/yr)	1,571,181	248,957	342,334	565,202	141,707	180,904	606,897
unappropriated (ac-ft/yr)	1,273,865	244,674	339,150	564,114	133,734	168,103	522,720
diversion targets (ac-ft/yr)	658,511	46,807	10,103	1,434	54,132	16,870	195,059
diversions (acre-feet/year)	564,069	21,299	2,031	1,051	27,438	12,454	146,773
shortage (acre-feet/year)	94,443	25,508	8,072	383	26,694	4,416	48,286
reliability (percentage)	85.66%	45.50%	20.10%	73.31%	50.69%	73.82%	75.25%
Additional Information Associated with Separating Evaporation and Precipitation							
evap-precip (ac-ft/year)	2,135	8,321	1,772	529	410	-75	-5,814
evaporation (ac-ft/year)	137,886	15,143	3,755	1,758	2,651	1,424	24,587
precipitation (ac-ft/year)	135,750	6,822	1,983	1,230	2,241	1,499	30,400
evap-precip (inches/year)	0.74	32.03	27.56	16.25	7.48	-2.39	-9.92
evaporation (inches/year)	47.83	58.30	58.40	54.03	48.31	45.42	41.93
precipitation (inches/year)	47.09	26.26	30.84	37.79	40.84	47.81	51.85
surface area (acres)	34,595	3,117	772	391	658	377	7,036
mean storage (acre-feet)	528,503	29,214	5,764	1,119	5,418	2,946	21,409

Table 5.4 – Individual Reservoir Summaries for Rio Grande River Basin

reservoir	Amistad/Falcon TX	Red Bluff
river basin	Rio Grande	Rio Grande
river	Rio Grande	Rio Grande
Information from Original TCEQ WAM System		
flood control (acre-feet)	-	-
conservation (acre-feet)	3,223,593	300,000
mean storage (acre-feet)	440,781	19,469
evaporation-prec (ac-ft/yr)	105,760	3,996
naturalized flow (ac-ft/yr)	1,099,597	124,194
unappropriated (ac-ft/yr)	48,999	217
diversion targets (ac-ft/yr)	2,017,696	66,625
diversions (acre-feet/year)	1,396,447	12,883
shortage (acre-feet/year)	621,249	53,742
reliability (percentage)	69.21%	19.34%
Separating Evaporation and Precipitation		
evap-precip (ac-ft/year)	206,320	4,894
evaporation (ac-ft/year)	290,993	6,186
precipitation (ac-ft/year)	83,216	1,292
evap-precip (inches/year)	24.59	53.36
evaporation (inches/year)	34.68	67.45
precipitation (inches/year)	9.91	14.09
surface area (acres)	100,694	1,101
mean storage (acre-feet)	926,143	19,475

Diversion shortages represent the amount of water that was not supplied to the targeted diversion. These river basin components help provide insight to the current water supply conditions.

As illustrated in Table 5.3 the Trinity, Sabine, Colorado, Brazos, Red, and Neches river basins have reservoir storage capacities greater than 3,500,000 acre-feet. High reservoir storage capacities are to be expected because these basins have a large number of reservoirs. In addition the average sizes of the reservoirs are very large and have an average surface area greater than 75,000 acres. Basins with the smallest reservoir capacities are located along the Gulf of Mexico and include the Upper Nueces-Rio Grande, San Antonio Nueces, Colorado Lavaca, and Trinity San Jacinto river basins. The average surface area of reservoirs in these basins is less than 800 acres. A reason these river basins have such small reservoir storage capacities is that they are located at the most downstream portion of major rivers therefore having small water supply demands.

As seen in Table 5.3 the Brazos, Trinity, Sabine, Red, and Colorado river basins experience a great amount of net evaporation-precipitation for their corresponding period of analysis. Net evaporation-precipitation volumes are computed by multiplying the reservoir water surface area by net evaporation-precipitation rates. As previously stated the reservoirs in these basins have large water surface areas thus contributing to large evaporation-precipitation volumes in these river basins. The Upper and Lower Nueces-Rio Grande are two smaller river basins that experience high evaporation-precipitation volumes. These basins have small reservoir storage capacities but are located in portions of the state that experience high evaporation rates, therefore producing such large volumes.

In evaluating the impact evaporation suppression has on water supply availability/reliability it is important to understand current volume reliabilities in each of the river basins. Volume reliability is defined as the ratio of the actual diversion volume supplied to the diversion target volume, converted to a percentage. The Sabine, Sulphur, and Brazos are the three river basins with the highest volume reliabilities. These basins are located in the eastern region of the state where precipitation is high and evaporation rates are low. Basins located in this general area typically have high volume reliabilities because of ideal weather conditions for maintaining surface water supplies. Basins with volume reliabilities 60% or lower include the Cypress, Colorado, Lavaca, Lower and Upper Nueces-Rio Grande, and Colorado Lavaca river basins. The diversion targets in each of these basins are much larger than reservoir storage capacities. In addition a majority of these basins have a small number of reservoirs and are located in regions that experience high evaporation rates and low annual precipitation. As a result it is difficult to meet water supply diversion targets. River basin summaries are provided in greater detail in Table 5.3.

Individual reservoir summaries for the Rio Grande river basin are provided in Table 5.4. The three reservoirs studied include Amistad, Falcon and Red Bluff reservoirs. Only these reservoirs were selected for evaporation suppression studies because they represent a majority of total reservoir storage in the Rio Grande river basin.

In reviewing water resources of the Rio Grande river basin it is important to note that the WAM dataset has been established to simulate water allocation and management scenarios in Texas and Mexico. This was done by creating two interconnected parallel water systems in which water resources for Texas and Mexico are separated. Amistad and Falcon Reservoirs both have international water rights while Red Bluff Reservoir does not. Current water resource conditions for Amistad and Falcon reservoirs are reported together in Table 5.4 because these reservoirs operate as a system when supplying water supply diversion along the Rio Grande from Amistad to the Gulf of Mexico. When performing evaporation studies, evaporation suppression was applied to the total reservoir water surface including both Texas and Mexico water surface. Results reported in Table 5.4 only pertain to the Texas allocation.

As shown in Table 5.4 the Texas portion of Amistad and Falcon Reservoir have a combined conservation storage capacity of 3,223,593 acre-feet while Red Bluff Reservoir has a conservation storage capacity of 300,000 acre-feet. These three reservoirs combined have a similar conservation storage capacity to that of the Neches river basin. Although these three reservoirs have high conservation storage capacities, an arid climate with high evaporation rates severely limits the amount of water supplies available. The mean storage capacity for Amistad and Falcon Reservoir is 440,781 acre-feet and 19,469 acre-feet for Red Bluff Reservoir. This represents 13.7% and 6.5% of the reservoirs conservation capacity. As a result of having low storage capacities, volume reliability is relatively low for all three reservoirs. Amistad and Falcon reservoirs have a combined volume reliability of 69.21% while Red Bluff's is 19.34%.

Volume reliability for Amistad and Falcon is based on Texas diversions only. A majority of the Rio Grande river basin receives stream flow from Amistad and Falcon Reservoir. According to Table 5.4 Amistad and Falcon Reservoir provide Texas with a naturalized flow of 1,099,597 acre-feet/year with Red Bluff only provides 124,194 acre-feet/year. Due to a dwindling supply of water unappropriated flows for the three reservoirs tend to be extremely low. Amistad and Falcon Reservoir has 48,999 acre-feet of unappropriated flow while Red Bluff has 217 acre-feet. These values show how limited water supply resources are in the Rio Grande river basin. Naturalized and unappropriated flows for Amistad and Falcon Reservoir represent the Texas portion of flows at the outlet of the basin.

As previously discussed a variety of analyses were performed for specified percentages of reservoir storage capacities and evaporation reduction rates. River basin simulation results detailing river basin volume budgets, water supply diversions, shortages, volume reliabilities, reservoir storage capacities, reservoir storage frequency tables, and reservoir evaporation volumes can be found in Appendix B.

Since a major focus of this study was centered on reservoir evaporation suppression, a river basin summary of evaporation volumes at various evaporation reduction percentages is provided in Table 5.5. Values in the table correspond to evaporation reductions at 100% of reservoir storage capacity.

Results in Table 5.5 indicate that the mean annual evaporation for the 19 river basins used in the analysis is 5,558,941 acre-feet/year and 5,842,592 acre-feet/year when Amistad, Falcon and Red Bluff Reservoir are added. This is a significant amount of volume and represents 10.3% of the original (before sedimentation) storage capacity of the reservoirs in the 19 river basis from the TCEQ WAM system. Results indicate that evaporation volumes are not reduced to the exact amount specified in the *JD* record used in WRAP-SIME. Actual evaporation volumes are typically reduced by 3 to 9 percent lower. Even though reservoir surface evaporation rates are reduced by the specified amount (10%, 25%, 50%, 100%), the reservoir evaporation volumes computed are dependent on reservoir storage levels in the basin. This is attributed to the fact that evaporation volumes are computed each month by multiplying the evaporation depth times the average water surface area determined as a function of storage volume which is constantly changing. The mean annual evaporation volume with a 10% reduction is 5,361,407 acre-feet/year; 4,576,311 acre-feet/year at a 25% reduction, and 3,180,723 acre-feet/year at a 50% reduction.

In reviewing Table 5.5 the majority of reservoir evaporation volumes occur in the Trinity and Sabine River Basins. Although these basins are in portions of the state that tend to have low evaporation rates, volumes are large because there are numerous reservoirs in these basins that have extremely large surface areas. River basins with small evaporation volumes include the Lower and Upper Nueces-Rio Grande, Colorado-Lavaca, and Trinity-San Jacinto river basins. Although these basins have evaporation volumes of less than 30,000 acre-feet/year, their corresponding volumes represent more than 50% of the mean reservoir volume. This represents a significant proportion of water supply in these basins and illustrates that much of the reservoir surface water is lost to evaporation.

Table 5.5 – Evaporation Summary

Map ID	River or Coastal Basin or Individual Reservoir	Evaporation Reduction (Percent) 0	10	25	50	100
		Evaporation (acre-feet/year)				
	River Basins					
1	Canadian River	73,267	67,143	57,823	41,174	0
2	Red River	616,551	570,428	491,543	346,553	0
3	Sulphur River	218,858	198,967	167,410	113,100	0
4	Cypress Boyou	189,720	173,886	147,189	99,977	0
6	Colorado River	371,403	344,525	296,786	218,758	0
7	Brazos River	817,336	753,928	650,574	462,093	0
8	Trinity River	1,190,660	1,090,813	927,114	637,883	0
9	Neches River	648,868	591,340	501,249	342,183	0
10	Sabine River	1,001,309	914,286	771,300	523,887	0
11	Nueces River	93,695	86,733	75,807	56,138	0
12	Guadalupe San Antonio	90,653	83,477	74,874	50,247	0
13	Lavaca River	59,317	53,838	45,184	30,399	0
14	San Jacinto River	137,886	126,480	107,674	74,116	0
15	Lower Nueces-RG	15,243	14,729	14,088	13,683	0
16	Upper Nueces-RG	3,755	3,581	3,293	2,968	0
17	San Antonio-Nueces	1,758	1,632	1,421	1,009	0
19	Colorado-Lavaca	2,651	2,417	2,050	1,402	0
20	Trinity-San Jacinto	1,424	1,315	1,110	751	0
21	Neches-Trinity	24,587	23,707	21,583	15,481	0
	Total - 19 River Basins	5,558,941	5,103,225	4,358,072	3,031,802	0
	Rio Grande Reservoirs					
	Amistad	78,520	70,698	59,172	39,604	0
	Falcon	198,945	181,845	154,276	106,012	0
	Red Bluff	6,186	5,639	4,792	3,305	0
	Total - 3 Reservoirs	283,651	258,182	218,239	148,921	0
	Statewide Total	5,842,592	5,361,407	4,576,311	3,180,723	0

If evaporation is suppressed by 50% in the Lower Nueces-Rio Grande basin there will be a 10% increase in water volume available for water supply. Water volumes will increase by 20.9% in the Upper Nueces-Rio Grande at a 50% reduction in evaporation rates. Both the Colorado-Lavaca and Trinity San Jacinto basin will see a 47% volume increase if a 50% reduction in evaporation is achieved.

Table 5.5 illustrates that 283,651 acre-feet/year of reservoir water supply is lost to evaporation in the three largest reservoirs of the Rio Grande river basin. Although Amistad and Falcon Reservoir have roughly the same reservoir surface area Falcon loses a greater volume of water to evaporation. This is mainly due to being located in a region that experiences higher evaporation rates. Red Bluff Reservoir loses 6,186 acre-feet/year to evaporation. At first this value may not seem like a great amount of volume but it is nearly 32% of the mean reservoir volume. When comparing the total evaporation loss from Amistad, Falcon and Red Bluff Reservoir it is similar to that of the Sulphur river basin. However, evaporation volumes do not change by a great amount as evaporation rates are reduced.

Evaporation volumes reported in Table 5.5 are based on a trigger of 100% of reservoir storage capacity. Reservoir evaporation volumes computed at 75%, 50%, and 25% of reservoir storage capacity are lower. This is because reductions are not made until reservoir levels are lower which means the corresponding surface areas used to compute the volumes are much smaller. At a trigger of 25% reservoir storage capacity the mean annual evaporation volume with a 10% reduction is 5,255,534 acre-feet/year;

4,394,008 acre-feet/year at a 25% reduction, and 3,162,784 acre-feet/year at a 50% reduction.

As indicated by the evaporation summary table, a large amount of water in each river basin is lost to reservoir surface evaporation. Reductions in reservoir evaporation greatly change various components of basin reservoir/river system operations. In order to understand the role reservoir evaporation plays on reservoir/river system operations, changes in water right diversions, reservoir storage, regulated flows at river basin outlets, and other changes were analyzed. Table 5.6 provides a summary of changes in volume budge components resulting from 100% evaporation suppression.

When decreasing reservoir evaporation volumes it is reasonable to expect that several hydrologic changes would occur on a basin level basis. It is logical to expect that reservoir storage levels would increase because less water is being evaporation from the surface. Reservoir storages are calculated by taking the difference from the end-of-month storage and beginning-of-month storage. Results in Table 5.6 indicate that at 100% evaporation suppression the average reservoir storage is increased by 100,880 acre-feet/year for the 19 river basins. The three river basins with the largest storage increase are the Trinity, Colorado, and Neches. Average reservoir storage for Amistad, Falcon, and Red Bluff Reservoir is increased 102-983 acre-feet/year. A majority of the increase is from Amistad and Falcon Reservoirs since they are the two largest reservoirs in the Rio Grande river basin. Just these two reservoirs alone have a larger increase in storage volume than the 19 river basins combined. Therefore there is great potential to increase water resources in the Rio Grande basin by implementing evaporation suppression techniques.

A decrease in the amount of reservoir surface water lost to evaporation increases the amount of water supply available for meeting targeted diversions. If a greater volume of diversion targets are met, diversion shortages should decrease. Table 5.6 illustrates that the total actual diversions for the 19 river basins are increased by 6,398,412 acre-feet/year and when 100% of evaporation is suppressed. The three Rio Grande reservoirs increase diversions by 51,222 acre-feet/year. Similar to storage increase results, a majority of diversion increases are experienced by the Amistad and Falcon reservoir system. Red Bluff Reservoir diversions are only increased 527 acre-feet/year. Basins with the largest diversion increases include the Colorado, Trinity, and Guadalupe-San Antonio river basins. Although reservoir evaporation is only decreased by 90,653 acre-feet/year in the Guadalupe San Antonio River Basin, there is a diversion increase of 285,565 acre-feet/year in the Guadalupe San Antonio River Basin. This basin is relatively small but its TCEQ WAM dataset has 848 water right records which is the fourth largest among the 19 river basins studied. Due to reduce evaporation volumes a greater number of diversion targets are met therefore producing a large change in annual diversion amounts. Guadalupe San Antonio evaporation suppression results in Appendix B show that there is annual increase in division volumes as the reductions in evaporation are increased. As expected the increase in diversions become lower as reservoir storage capacity evaporation suppression triggers are reduced.

Table 5.6 – Changes to Volume Budget Components Resulting from 100% Evaporation Suppression

Map ID	River or Coastal Basin or Individual Reservoir	Evaporation Redution (ac-ft/yr)	Diversion Increase (ac-ft/yr)	Storage Increase (ac-ft/yr)	Flow Increase (ac-ft/yr)	Other Changes (ac-ft/yr)
	River Basins					
1	Canadian River	73,267	42,744	3,952	40,361	34,175
2	Red River	616,551	20,394	13,673	589,413	59,017
3	Sulphur River	218,858	2,113	831	220,325	5,709
4	Cypress Boyou	189,720	42,767	1,423	187,828	2,882
6	Colorado River	371,403	5,318,960	18,979	299,333	29,264
7	Brazos River	817,336	56,495	9,695	610,472	232,821
8	Trinity River	1,190,660	516,601	28,550	1,046,175	70,571
9	Neches River	648,868	17,162	17,141	675,453	2,974,575
10	Sabine River	1,001,309	4,881	88	1,064,196	4,018
11	Nueces River	93,695	51,978	442	46,464	44,102
12	Guadalupe San Antonio	90,653	285,565	2,053	64,324	25,242
13	Lavaca River	59,317	13,983	538	57,548	1,514
14	San Jacinto River	137,886	16,187	2,101	141,097	7
15	Lower Nueces-RG	15,243	5,161	1,234	21,526	889
16	Upper Nueces-RG	3,755	185	37	4,600	535
17	San Antonio-Nueces	1,758	120	1	1,721	154
19	Colorado-Lavaca	2,651	190	8	2,643	0
20	Trinity-San Jacinto	1,424	167	11	1,364	0
21	Neches-Trinity	24,587	2,759	123	12,555	13,524
	Total - 19 River Basins	5,558,941	6,398,412	100,880	5,087,398	3,498,999
	Rio Grande Reservoirs					
	Amistad and Falcon	290,993	50,695	100,996	74,098	174,464
	Red Bluff	6,186	527	1,987	4,613	120
	Total - 3 Reservoirs	297,179	51,222	102,983	78,711	174,584
	Statewide Total	5,856,120	6,449,634	203,863	5,166,109	3,673,583

In evaluating the impact of evaporation suppression on diversions it is important to review percentage increases. The river basin which experiences the large percentage increase in water supply diversions is the Canadian river basin. With a 10% reduction in evaporation rates diversions are increased by 4.29%; at a 100% reduction there is a 13.05% increase in additional diversions supplied. The Lower Nueces-Rio Grande coastal basin also experiences a large percentage increase in the amount of additional diversion supplied. Diversions are increased by 1.23% at a 10% reduction in evaporation and 15.72% at a 100% reduction. The third largest diversion percentage increase, 5.06% at 100% reduction, is in the Nueces river basin. Red Bluff Reservoir water supply diversions are only increase 4.09% with a 100% reduction in evaporation. Diversions are only increased by a very small amount because reservoir storage levels remain empty during much of the year.

Another volume budget component impacted by the reduction in reservoir evaporation is regulated flows at the river basin outlet. Total regulated flows for the 19 river basins are increased by 5,087,398 acre-feet/year with 100% evaporation suppression at 100% of reservoir storage capacity. The river basins with the greatest increase in regulated flows at the outlet include the Sabine, Trinity, Neches, Brazos, and Red River Basin. These basins have the largest reservoir storage capacities and thus it is expected that regulated flows should larger. Regulated flows for the Rio Grande river basin are increased by 78,711 acre-feet/year. As a result of having high regulated flows any changes would lead to large increase in flows throughout the basin including unappropriated flows. Naturalized flows would remain the same because they are independent of reservoir releases.

5.3 Water Supply Reliability

The main focus of reservoir evaporation suppression studies is to determine the impact on water supply availability/reliability. Table 5.7 provides a summary of volume reliability as it varies with evaporation reduction percentages at 100% of reservoir storage capacity. Additional results can be found in Appendix B. Results indicated that river basins in the eastern part of the state tend to have a higher volume reliability than those in the western part and this is mainly due to climatic conditions. Eastern parts of Texas experience high precipitation and low evaporation rates therefore increasing the amount of water available for meeting target demands.

The two river basins with the highest average volume reliability for the five reduction percentages at 100% of reservoir storage capacity are the Sulphur and Sabine river basins. Both these basins are located along the eastern border of the state where climatic conditions are ideal for producing high volume reliabilities. The Sabine river basin has one of the largest reservoir capacities and therefore is able to supply a great amount of water to meet the targeted diversions. In addition, this river basin has reservoirs with very large surface areas. Therefore various reductions in evaporation rates greatly reduce the volume of water lost to evaporation. Although the Sulphur river basin has reservoirs with much smaller storage capacities, volume reliabilities are high because reservoirs mean storage levels are near the total storage capacity. As a result a great amount of surface water is available to meet additional water supply demands in the basin. Another reason the Sulphur river basin has high volume reliabilities is that the total diversions are relatively low and are easier to meet.

The San Jacinto river basin has the third highest volume reliability out of the 19 river basins under investigation. This basin is located in east Texas and is bordered by the Trinity river basin to the north, the Brazos river basin to the west and south, and the Trinity-San Jacinto coastal basin to the east. Although the river basin has a large population in Harris County, the volume reliability is high because annual rainfall ranges between 35 to 79 inches. As reductions are made in evaporation, reservoir levels increase because of high precipitation rates. This results in higher reservoir levels thus increasing the amount of water supply available for supplying water right diversions. Results in Table 5.7 for the Rio Grande river basin show that Red Bluff Reservoir has extremely low volume reliabilities. The current reliability is 19.33% and it is only increased 0.79% with 100% evaporation suppression. These low reliabilities are a result of Red Bluff Reservoir having low exceedance frequencies. During a majority of the year Red Bluff Reservoir is empty and never refills to meeting additional water supply diversions. Amistad and Falcon combined have a volume reliability of 69.72%. As reductions are made to evaporation rates, volume reliability reaches a maximum percentage of 72.23

Table 5.7 – Reliability Summary

Map ID	River or Coastal Basin or Individual Reservoir	Evaporation Reduction (Percent) 0	10	25	50	100
		Volume Reliability (Percent)				
	River Basins					
1	Canadian River	73.16	76.30	80.65	87.62	99.11
2	Red River	88.66	88.89	89.33	90.10	92.26
3	Sulphur River	98.80	98.94	99.08	99.19	99.38
4	Cypress Boyou	57.35	58.47	60.29	63.28	69.07
6	Colorado River	18.50	18.59	18.71	19.01	19.57
7	Brazos River	90.03	90.33	90.78	91.42	92.51
8	Trinity River	72.41	73.54	75.32	78.42	84.94
9	Neches River	87.34	87.41	87.50	87.59	87.68
10	Sabine River	98.80	98.83	98.84	98.89	98.99
11	Nueces River	77.68	77.97	78.54	79.56	82.75
12	Guadalupe San Antonio	72.26	72.45	72.78	73.37	74.68
13	Lavaca River	54.42	52.61	52.94	53.98	55.95
14	San Jacinto River	92.34	92.78	93.44	94.05	95.50
15	Lower Nueces-RG	45.50	46.07	46.98	48.84	56.52
16	Upper Nueces-RG	20.10	20.20	20.35	20.61	21.93
17	San Antonio-Nueces	73.31	74.21	75.76	78.05	81.67
19	Colorado-Lavaca	50.66	50.70	50.77	50.87	51.03
20	Trinity-San Jacinto	73.82	73.82	73.96	74.20	74.84
21	Neches-Trinity	76.41	76.60	76.98	77.35	77.82
	Total - 19 River Basins	69.56	69.93	70.68	71.92	74.54
	Rio Grande Reservoirs					
	Amistad and Falcon	69.72	69.96	70.33	70.97	72.23
	Red Bluff	19.33	19.46	19.56	19.64	20.12
	Total - 3 Reservoirs	44.53	44.71	44.95	45.31	46.18
	Statewide Total	57.04	57.32	57.81	58.61	60.36

In evaluating the impact of evaporation suppression it is important to consider incremental volume reliability changes. Results in Table 5.7 indicate that the Canadian River Basin experiences the largest incremental increase as evaporation reduction percentages are altered. At a 10, 25, 50 and 100% reduction in evaporation rates, volume reliability is incrementally increased by 3.14, 7.49, 14.46, and 25.95%. When analyzing annual precipitation and evaporation amounts it is clear why this river basin would see such large incremental volume reliability increases. Evaporation rates are much higher than average annual precipitation amounts; therefore any reduction would greatly impact water supply volumes available for use. Another factor that would cause such large incremental increases are current reservoir levels. As seen in Table 5.8 mean storage levels are greatly increased as evaporation reductions are made. These large increases directly impact the amount of water that can be diverted to meet water supply demands.

Another river basin whose volume reliability is greatly impacted by evaporation reductions is the Lower Nueces-Rio Grande River Basin. This region of the state is currently experiencing a high level of drought because of high evaporation rates and low annual precipitation. As a result there is a limited water supply available for meeting target demands. Similar to the Canadian River Basin reduction in evaporation rates greatly alter volume reliabilities. Incremental volume reliability increases are as follows: 0.57, 1.48, 3.34, and 11.02%. Although there is great potential to increase volume reliability the maximum achievable reliability is 56.52% at 100% evaporation suppression applied at 100% of reservoir storage capacity. This is the result of reservoirs having low average storage trends.

In evaluating other river basins, volume reliabilities are not increasing by a great amount. There are also several basins with reliabilities below 60% including Cypress, Lavaca, Lower Nueces-Rio Grande, Upper Nueces-Rio Grande, and the Colorado-Lavaca River Basin. The reason for low volume reliabilities in the Cypress River Basin is that there are several water rights with high diversion targets that are constantly not being met. One example is WR B270DM which has a target of 17,743 acre-feet. Even with 100% evaporation reduction at 100% reservoir storage capacity, the diversion shortage only decreases by roughly 1,000 acre-feet which produces low volume reliabilities. Similarly the Lavaca River Basin has lower volume reliabilities because several diversions targets are not met due to having several instream flow requirements which must be met. This limits the amount of water that can be used to meet water rights. The Lower Nueces-Rio Grande, Upper Nueces-Rio Grande, and the Colorado-Lavaca River Basin have low volume reliability largely due to the fact that they lack reservoirs with large storage capacities. Since a majority of the reservoirs in these basins are small, reservoir drawdown levels tend to be drastic with each water supply diversion that is met.

5.4 Reservoir Storage Contents

The goal of evaporation suppression simulations is to see how water supply reservoirs storages change at different reduction percentages. Table 5.8 and Table 5.9 provide mean and minimum reservoir storage content result summaries for evaporation suppression at 100% of reservoir storage capacity. All the values for each of the 19 river basins are aggregate averages from the entire river basin.

Table 5.8 results indicate that the river basins that have the greatest average incremental increase are the Trinity, Brazos, and Colorado River Basins. This is largely due to having several reservoirs with conservation storage capacities over 100,000 acre-feet. Additionally the reservoirs have large surface areas. As reservoir storages increase with higher and higher reductions in evaporation, the mean basin storages greatly increase. Although there may not be a large increase in the level of reservoirs, large surface areas help contribute to the mean storage increases. River basins, such as the Canadian and Lower Nueces-Rio Grande, located in portions of the state that experience high evaporation rates also experience great increases in reservoir mean storage volumes. At a 10% evaporation reduction, the mean reservoir storage in the Canadian River Basin increases by 11,733 acre-feet. If evaporation is able to be reduced by 50% the mean storage increases from 539,952 acre-feet to 640,754 acre-feet. Although mean reservoir storage volumes are significantly less in the Lower Nueces-Rio Grande River Basin, there is an increase of 1,674 and 30,598 acre-feet at a 10 and 50% reduction. This represents a 5.7% and 104.4% increase in mean storage volume. These percentage increases are the largest among the 19 river basins experiencing evaporation reductions.

Mean reservoir storage content results for the three Rio Grande Reservoirs evaluated are provided in Table 5.8. The values reported only pertain to the Texas storage portion. Amistad has a mean storage capacity of 676,702 acre-feet/year while Falcon Reservoir is at 249,442 acre-feet/year. The mean reservoir storage level is extremely low for Red Bluff and is 19,475 acre-feet/year. These three reservoirs combined have a mean storage capacity of 945,619 acre-feet/year. This would rank as the seventh largest capacity when compared to the other 19 river basins. Mean storage volumes for Amistad Reservoir are increased at 63,423 acre-feet/year, 37,572 acre-feet/year for Falcon Reservoir and 1,987 acre-feet/year with no evaporation. This represents a 9.4% increase in volume for Amistad Reservoir, 15.1% for Falcon and 10.2% for Red Bluff.

Table 5.8 – Mean Reservoir Storage Contents

Map ID	River or Coastal Basin or Individual Reservoir	Evaporation Reduction (Percent) 0	10	25	50	100
		Mean Storage (acre-feet)				
	River Basins					
1	Canadian River	539,952	551,685	579,548	640,754	814,901
2	Red River	3,317,959	3,321,142	3,326,107	3,335,621	3,338,651
3	Sulphur River	614,168	620,845	629,941	642,852	662,474
4	Cypress Boyou	674,058	686,249	701,300	722,750	769,070
6	Colorado River	3,019,175	3,045,799	3,073,421	3,216,360	4,132,299
7	Brazos River	3,524,674	3,595,130	3,708,590	3,932,503	4,302,629
8	Trinity River	5,134,741	5,222,946	5,352,262	5,573,861	6,002,287
9	Neches River	3,390,582	3,434,763	3,508,760	3,620,757	3,763,724
10	Sabine River	5,698,497	5,784,837	5,884,873	6,025,061	6,227,589
11	Nueces River	273,915	281,283	295,476	326,215	409,001
12	Guadalupe San Antonio	585,094	594,176	607,289	628,212	660,601
13	Lavaca River	207,342	208,951	211,151	213,819	218,783
14	San Jacinto River	528,503	541,054	557,487	586,313	617,548
15	Lower Nueces-RG	29,313	30,987	34,909	59,912	93,527
16	Upper Nueces-RG	5,764	5,927	6,226	7,368	8,588
17	San Antonio-Nueces	1,119	1,154	1,209	1,300	1,339
19	Colorado-Lavaca	5,418	5,477	5,572	5,721	5,923
20	Trinity-San Jacinto	2,946	3,047	3,097	3,156	3,247
21	Neches-Trinity	21,409	22,426	23,019	23,669	24,341
	Total - 19 River Basins	27,574,630	27,957,877	28,510,236	29,566,202	32,056,520
	Rio Grande Reservoirs					
	Amistad	676,702	681,076	688,717	704,945	740,125
	Falcon	249,442	252,250	256,516	265,540	287,014
	Red Bluff	19,475	19,654	19,936	20,418	21,462
	Total - 3 Reservoirs	945,619	952,980	965,169	990,903	1,048,601
	Statewide Total	28,520,249	28,910,857	29,475,405	30,557,105	33,105,121

Table 5.9 – Minimum Reservoir Storage Contents

River or Coastal Basin or Individual Reservoir	Evaporation Reduction (Percent) 0	10	25	50	100
	Minimum Storage (acre-feet)				
River Basins					
Canadian River	373,573	373,573	390,878	397,915	528,364
Red River	2,330,080	2,452,039	2,652,615	2,972,440	3,431,019
Sulphur River	280,795	298,422	329,122	390,907	493,986
Cypress Boyou	244,731	268,541	305,670	365,718	477,177
Colorado River	1,462,863	1,527,730	1,314,587	1,613,052	2,657,413
Brazos River	1,554,376	1,715,154	1,927,391	2,400,436	3,575,555
Trinity River	538,127	737,224	1,019,597	1,718,294	3,215,810
Neches River	1,769,911	1,907,477	2,222,823	2,645,009	3,143,904
Sabine River	3,078,556	3,321,978	3,706,766	4,351,902	5,216,615
Nueces River	3,193	3,314	3,708	6,160	28,808
Guadalupe San Antonio	24,929	31,529	39,801	84,360	237,759
Lavaca River	60,152	69,202	82,509	84,353	106,219
San Jacinto River	64,053	76,165	114,276	265,419	478,354
Lower Nueces-RG	15,774	16,611	18,932	36,184	86,144
Upper Nueces-RG	3,529	3,745	4,234	5,508	8,197
San Antonio-Nueces	402	455	574	933	1,223
Colorado-Lavaca	1,939	2,147	2,497	2,994	3,645
Trinity-San Jacinto	253	266	290	313	326
Neches-Trinity	11,297	12,034	12,621	13,658	13,965
Total - 19 River Basins	11,818,534	12,817,606	14,148,888	17,355,551	23,704,482
Rio Grande Reservoirs					
Amistad	194,209	193,705	193,280	184,621	191,274
Falcon	35,899	35,715	35,011	39,562	35,113
Red Bluff	0	0	0	0	0
Total - 3 Reservoirs	230,108	229,420	228,291	224,183	226,387
Statewide Total	12,048,642	13,047,026	14,377,179	17,579,734	23,930,869

Minimum reservoir storage contents changes were also evaluated as part of evaporation suppression simulation studies. This is of particular importance for water supply capabilities because as reservoir storages become extremely low, it is crucial to maintain reservoir storage capacities to help achieve high water supply availability/reliability. Some of the river basins with the lowest minimum storage values are the Colorado-Lavaca, San Antonio-Nueces, and Trinity-San Jacinto Coastal Basins. Each of these river basins have a very small number of reservoirs with the largest being 13 in the Trinity-San Jacinto Coastal Basin. Minimum storage is increased by 208, 558, 1,055, and 1,706 acre-feet/year at evaporation reductions of 10, 25, 50, and 100% in the Trinity-San Jacinto Coastal Basin. Reservoir storage contents in this basin are nearly increased to double the existing minimum storage amount. Similar results occur in the San Antonio-Nueces Coastal Basin. Minimum storages are increased from 402 acre-feet/year to 455, 574, 933, and 1,223 acre-feet/year. These are very large increases considering that the total reservoir conservation storage is 1454.1 acre-feet. Minimum storage is increased by 20 acre-feet with every percentage reduction in evaporation. Results for the Rio Grande river basin show that the minimum storage for Red Bluff Reservoir is 0 acre-feet/year. Although evaporation reductions are made the minimum storage is never increased. Therefore evaporation suppression implementation may not be a viable solution at increasing minimum storage levels in this reservoir. Amistad and Falcon minimum storage volumes mainly decrease as evaporation reductions are specified by different simulation scenarios. Minimum storage responses to evaporation reduction are unique in Amistad and Falcon Reservoirs. Unlike a majority of river basin reservoir responses, as reductions are made to evaporation rates, minimum storage volumes for Amistad Reservoir decrease. Minimum storage volumes decrease because a greatly amount of water is being diverted from the reservoir to meeting water demands in the Rio Grande river basin.

In addition to reviewing minimum storage increases on a volume basis, percentage increases were also evaluated in the Colorado-Lavaca, San Antonio-Nueces, and Trinity-San Jacinto Coastal Basins. Out of these three basins the greatest percentage increase occurs in the San Antonio-Nueces river basin. Mean storage is increased by 13.3, 42.8, 132.2 and 204.4% at a 10, 25, 50 and 100% reduction in the evaporation rates. There is a 10.7, 28.8, 132.2 and 204.4% increase in mean storage volumes in the Colorado-Lavaca river basin. Minimum storage volumes in the Trinity-San Jacinto river basin are increased by 5.1, 14.6, 54.4, and 88.0% at the specified reduction rates.

River basins with the largest minimum storage percentage increases are the Trinity, Guadalupe-San Antonio and San Jacinto river basins. There is a 37.0, 89.5, 219.3 and 497.6% increase in minimum storage volume in the Trinity river basin with a 10, 25, 50 and 100% reduction in the evaporation rates. Minimum storage volumes in the Guadalupe-San Antonio river basin are increased by 26.5, 59.7, 238.4, and 853.7% at the specified reduction rates. There is an 18.9, 78.4, 314.4, and 646.8% increase in the San Jacinto river basin. Evaporation suppression studies illustrate that there is great potential to increase minimum storage volumes if reductions are made to reservoir evaporation rates.

5.5 Evaporation Suppression based on Storage Triggers

In quantifying the impact of reservoir evaporation on water supply availability/reliability changes to river basin volume budget components were evaluated when applying evaporation suppression at different percentages of reservoir storage capacities. These analyses help provide insight on the response of reservoir/river system operations as reservoir levels become depleted. It is important to perform these evaluations because in times of drought it is imperative to maintain a reliable source of water supply. Evaporation suppression simulation results based on different storage capacity triggers can be found in Appendix B.

Reservoir storage exeedance frequencies help provide insight on the potential effectiveness of suppressing evaporation at varying percentages of reservoir storage capacities. Exceedance frequency tables show what percentages of the maximum reservoir storage capacity are equal or exceed 100, 99, 98, 95, 90, 80, 70, 60, 50, 40, 30, 20, and 10% of the simulation sequence time. Exceedance frequency results can be found in Appendix B.

As indicated by simulation results, reducing evaporation rates at various percentages of storage capacity does not greatly influence current water supply conditions. Result in Appendix B show that applying evaporation suppression at different percentages of storage capacity does little to impact river basin volume reliabilities. In some instance triggering evaporation suppression at low percentages of storage capacity does not change water supply conditions. This is attributed to reservoir storage volumes being below the trigger capacity a majority of the time.

5.6 Firm Yield Case Studies

In evaluating evaporation suppression impacts on river basin water supplies it is important to consider changes in firm yield. Wurbs and Bergman (1990) define firm yield as the estimated maximum release or withdrawal rate which can be maintained continuously during a repetition of the hydrologic period of record at 100% reliability. Firm yield case studies were performed for Lake Hubbard Creek, Proctor, and Red Bluff reservoir. Performing a firm yield analysis on a smaller scale helps provide better insight to individual reservoirs responses to reduced surface evaporation rates.

Lake Hubbard Creek is located in central Texas and lies within the Brazos river basin. It is a very large reservoir and has a conservation storage of 317,750 acre-feet. This reservoir was selected because it is located in a portion of the state that has high evaporation rates and low annual precipitation. Additionally water levels in the reservoir have a history of being low and dropped 13 to 14 feet during the 2008 drought. Proctor Lake is also in the Brazos river basin and is located Comanche County. Proctor Lake has similar climatic conditions to Lake Hubbard Creek because it is only a couple hundred miles away. This reservoir is also sensitive to drought and lake levels are often monitored during periods of low precipitation. Proctor Lake has a conservation storage of 59,400 acre-feet. Red Bluff reservoir is in the Rio Grande river basin and has a conservation storage of 300,000 acre-feet. This reservoir is located in an area of the state that has high evaporation rates and extremely low annual precipitation.

Firm yield analyses were performed using the full authorized use datasets. All analyses were performed using the evaporation suppression simulation study combinations found in Table 5.1.

When performing a base analysis for Hubbard Creek with no evaporation suppression it was determined that the firm yield was 21,600 acre-feet/year. According to the WAM dataset Hubbard Creek Reservoir has a total authorized diversion amount of 56,000 acre-feet/year. If no evaporation suppression is applied to this reservoir the 38.6% of the authorized amount is met. If 10% evaporation reduction is achieved the firm yield is increased to 25,296 acre-feet/year which is a 17.11% increase. Hubbard Creek Reservoir's firm yield is increased to 71,423 acre-feet/year if evaporation is completely suppressed. This is greater than the authorized diversion amount and is 22.45% of the total conservation storage. Since the storage volume never increases above 25% additional firm yield evaporation suppression analysis were not performed. Firm yield analysis results can be found in Table 5.10.

Firm yield analyses were performed for Proctor which is also located in the Brazos river basin. The base analysis shows that with no evaporation suppression the firm yield for Proctor Lake is 19,403 acre-feet/year. Firm yield is increased as a reservoir evaporation rates are reduced. At a 10% reduction the annual firm yield becomes 20,784 acre-feet; at a 25% reduction, 22,587 acre-feet; at a 50% reduction, 25,502 acre-feet and at a 100% reduction, 32,907 acre-feet.

The last firm yield analysis performed was for Red Bluff Reservoir. As was previously discussed Red Bluff's reservoir storage volumes are extremely low during the course of a year. Firm yield analysis reiterates that water supply is severely limited in this portion of the state. The base analysis indicates that there is no firm yield for Red Bluff Reservoir. If evaporation is reduced by 100% the firm yield for Red Bluff Reservoir is 281 acre-feet/year.

Table 5.10 Firm Yield Analysis Results

Individual	River	Evaporation Reduction (Percent)				
Reservoir	Basin	0	10	25	50	100
		Firm Yield (acre-feet/year)				
Hubbard Creek	Brazos	21,600	25,296	31,468	43,482	71,423
Proctor	Brazos	19,403	20,784	22,587	25,503	32,907
Red Bluff	Rio Grande	-	-	-	-	281

CHAPTER VI

SUMMARY AND CONCLUSIONS

The goal of this research is focused on assessing the impact of reservoir evaporation and potential impacts of reductions in reservoir evaporation on water supply capabilities in the state of Texas. This included developing a literature review based assessment on the capabilities of reducing reservoir evaporation by using monolayer films and other evaporation suppression methods. The TCEQ WAM System was used to develop/reservoir system water budgets and determine water supply reliabilities without and with evaporation suppression. Simulations performed in WRAP-SIME help provide a better understanding of Texas water resource responses to evaporation suppression and the feasibility of increasing state water supply through evaporation suppression techniques.

6.1 Literature Review Assessment

6.1.1 Texas Water Resources Overview

Texas is a large state with diverse water resources that include 3,700 named streams, 20 major aquifers, and 3,450 permitted reservoirs which include 196 major reservoirs with controlled storage capacities of 5,000 acre-feet or more. A majority of these reservoirs are located in the eastern part of the state where climatic conditions facilitate maintaining high reservoir volumes. This research evaluated reservoir water supply response on a basin by basin basis as evaporation reductions were specified. Basin wide reservoir evaporation suppression studies were performed on 19 out of the 21 WRAP input file datasets. Simulations were not performed for the Lavaca-Guadalupe Coastal basin because there are no reservoirs. Instead of performing a basin wide reservoir evaporation study on the Rio Grande river basin, evaporation suppression was only applied to three reservoirs (Amistad, Falcon and Red Bluff). These three reservoirs were selected for investigation because they represent a majority of the basins total reservoir storage capacity.

In reviewing Texas water resources it is important to understand the influence of regional climate variability on water supply availability/reliability. Generally speaking the eastern part of the state has the most ideal conditions for maintaining a good source of surface water supplies. This is mainly contributed to high annual precipitation rates and low annual evaporation rates. The opposite is true for the western part of the state, where precipitation is extremely low and evaporation rates are high. Due to these climatic conditions water resources are severely stressed and water supply reservoir volumes are limited.

6.1.2 Evaporation and Evaporation Suppression Review

The literature review provides a great deal of information regarding evaporation and evaporation suppression. Evaporation is a key process in the hydrologic cycle and a primary pathway through which water travels. There are several techniques available to estimate lake evaporation and evaluate evaporation suppression savings. These techniques include the pan evaporation method, a detailed water budget, combined energy budget and mass-transfer method and the simplified method.

The pan evaporation method is the simplest method that can be used to estimate reservoir evaporation but requires a conversion method to address short period inefficiencies. Conceptually the water budget method is among the simplest methods available for estimating open water evaporation. The water budget is used to determine lake evaporation by taking the difference in inflow and outflow. However, components require several measurements and observations. The combined energy budget and mass-transfer method used to estimate reservoir evaporation is very complex and requires several calculations. In an effort to reduce computation the simplified method was developed. Required inputs include film coverage factor, temperature-evaporation reduction factor, wind speed, and water vapor pressure gradient.

A number of evaporation suppression field investigations were reviewed. Suppression experiences were conducted using various monolayer materials and other physical barriers. Monolayer materials often included hexadecanol and octadecanol. Past studies performed by the United States Bureau of Reclamation reveal several inefficiencies of using monolayer films on large surface water reservoirs. The major problem with monolayer films is they are easily displaced by moderate to high winds. This greatly influenced the performance of evaporation suppression material. As a result typical evaporation reduction values between 10-30% were achieved. In order to help overcome film displacement on large water reservoirs it is recommended to use monolayer materials that spread easily when placed on a water surface. In addition they material must be able to repair spontaneously in order to reform a film and achieve maximum surface coverage. This will help ensure the highest possible evaporation reductions are achieved. Other techniques which can be used to address inefficiencies experienced during high wind speeds is to implement monolayer application systems that can adaptively manage monolayer dosages in response to changing environmental conditions. Recommended techniques include automatic dispensing units that are capable of adjusting to prevailing climatic conditions.

Past large scale evaporation suppression studies revealed that another major issue encountered during field investigations is film degradation. Factors attributing to the rapid breakdown of monolayer films mainly include bacteria consumption. Material degradation was also problematic in small scale evaporation suppression studies. These studies made use of materials such as foam rubber sheets, polystyrene sheets, foam and continuous wax blocks, and water shades. In order to overcome material degradation materials selected as evaporation suppressants should be durable, have high melting temperatures, and be minimally impacted by exposure to solar radiation.

The literature review assessment concludes that when considering evaporation suppression techniques monolayer films are suited for large reservoirs while water shades and floating covers are the most promising solution on smaller reservoirs. Although monolayer films may offer the best option for large reservoirs, achievable reduction rates range from 10% to 30%. Water shades and floating covers used on small reservoirs, such as ones used for agricultural purposes, reduce evaporation anywhere from 60% to 90%. Regardless of potential evaporation reductions an economic analysis should always be performed. Hexadecanol and octadecanol material have good evaporation suppression characteristics but can be expensive when constantly reapplied to a large reservoir surface. Water shades also perform well but require large startup cost because of installation and material. Therefore it is recommended to used water covers as a means of evaporation suppression on smaller water supply tanks. The evaporation suppression techniques reviewed as part of this research provide a reasonable solution for reducing evaporation rates and maintain current water supplies.

6.2 Evaporation Suppression Simulation Findings

Evaporation suppression simulations findings help provide a better understanding of the impact reservoir evaporation has on water supply availability/reliability. Simulation results show that 5,840,000 acre-feet of water is lost to reservoir surface evaporation each year. A majority of this evaporation lost occurs in eastern river basins such as the Trinity and Sabine river basins. Although these basins are in an area of the state that experience lower evaporation rates, evaporation volumes are large because there are numerous reservoirs with large storage volumes in these basins. Many of these reservoirs have extremely large surface areas which allow for increased evaporation volumes. The Lower and Upper Nueces-Rio Grande, Colorado-Lavaca, and Trinity-San

Jacinto river basin may have small evaporation volume losses but the loses represent more than 50% of the mean reservoir volumes in their respective river basin.

In reviewing evaporation suppression simulation results the Colorado-Lavaca and Trinity-San Jacinto river basins experience larger water volume increase as reductions are made to evaporation rates. Water volumes are increased 47% with a 50% reduction in evaporation while reservoirs in the Lower and Upper Nueces-Rio Grande only increase 12%. However, this does little to help increase low volume reliabilities in these basins. Reservoirs in river basins that are located in regions with high evaporation rates do not see a vast reduction in evaporation volumes at varying evaporation reduction rates. This is attributed to several factors. One factor contributing to low evaporation reduction volumes is that water supplies in western river basins are so severely limited which causes reservoir volumes to remain low during the course of the year. International Amistad and Falcon Reservoirs are among the largest in the state in storage capacity but tend to be drawn down much more than the large reservoirs in east Texas. Low reservoir volumes translate to smaller surface areas for which evaporation volumes can be reduced. Another contributing factor is that the number of reservoirs in western basins are relatively low.

In evaluating the feasibility of increasing water supply by means of evaporation suppression changes in basin water supply availability/reliability were evaluated. Results showed that reservoirs located in the eastern part of the state have much higher volume reliabilities than those located in west Texas. As evaporation reductions were made volume reliabilities do not dramatically increase. Volume reliability percentage increases typically ranged between 0.50% to 5.0%. River basins such as the Upper Nueces-Rio Grande and Rio Grande, which have a difficult time meeting targeted water supply demands, experienced very low volume reliability increases. Volume reliability improvements for these basins did not exceed a 2.50% increase at 100% evaporation suppression. Simulation results indicate that evaporation suppression does not greatly impact volume reliabilities in basins that have limited water resources. Therefore evaporation suppression may not be a reasonable solution at increasing annual water supply diversions.

River basin water resource components are greatly impacted by reservoir storage levels. Therefore changes to minimum and mean reservoir storage were investigated. Evaporation suppression simulations reveal that there is the potential to increase mean reservoir storage levels in river basins that have low volume reliabilities. However there is greater potential to increase minimum reservoir storage levels in multiple river basins across the state. These reservoirs are located along the gulf coast where evaporation rates are moderate to high. Through suppressing evaporation it allows for minimum storage volumes to increase because of the added volume received from precipitation. Although evaporation suppression greatly helps increase minimum storage capacities, the increase in volume is not enough to supply additional water demands throughout these basins.

6.3 Conclusions and Recommendations

Reservoir evaporation is a significant component of reservoir/river system water budgets in Texas and significantly affects water supply capabilities. About 3,435 reservoirs are included in the Texas water rights permit system and the TCEQ WAM System. The evaporation totals presented in this thesis represent 3,344 of these reservoirs, which excludes the smaller reservoirs in the Rio Grande Basin. These 3,344 reservoirs represent almost all of the reservoir storage capacity and reservoir water surface evaporation in Texas. Most of the evaporation occurs at the 200 largest reservoirs. The authorized use scenario simulations provide a reasonably accurate assessment of reservoir evaporation volumes and impacts on water supply statewide. Based on the simulations performed in this study, annual reservoir evaporation statewide is estimated to average about 5,840,000 acre-feet/year, varying greatly between years with fluctuations in storage levels and evaporation rates.

Comparison with other quantities provides a perspective on the relative magnitude of the 5,840,000 acre-feet/year mean annual evaporation. This aggregated total annual evaporation volume is equivalent to:

- 14.4 percent of the total conservation storage capacity of the 3,344 reservoirs
- 21.1 percent of the mean storage contents of the 3,344 reservoirs
- 23.6 percent of the total authorized (permitted) annual water supply diversion volume for agricultural, municipal, industrial, and other uses supplied by all streams and reservoirs in Texas

The volume reliability of the aggregated total of all authorized diversion rights in the state is 79.2 percent based on the simulation study presented in the thesis. The volume of all diversions, constrained by water availability, is 79.2 percent of the target demand. The volume reliability increases to 85.6 percent if all reservoir evaporation rates are changed to zero in the model. The mean reservoir storage volume increases by 16.0 percent with evaporation rates changed to zero.

Improvements in water supply capabilities that could potentially be achieved by evaporation suppression appear to be significant under appropriate circumstances, though the sensitivity of water supply diversion reliabilities to reasonable reductions in evaporation are not dramatic from an aggregated statewide perspective in the simulation study. Evaporation volumes are greater in the more humid eastern half of the state where most of the reservoir storage capacity is located. However, evaporation reductions can impact water supply capabilities more for reservoirs located in the drier western half of the state.

The timing of the application of evaporation suppression methods may be an important issue from the perspective of economic feasibility. Water supply reliabilities may be enhanced significantly even if the evaporation suppression is implemented only relatively infrequently during periods of significant reservoir storage depletion. In general, evaporation suppression improves water supply reliabilities only if the evaporation suppression contributes to the prevention of severe reservoir draw-downs. Evaporation suppression has little impact on supply reliabilities during periods of time when reservoir levels lower a little and then refill, either with or without evaporation suppression. Thus, the research investigated the concept of setting trigger levels with the evaporation suppression being applied only during times in which the reservoir storage contents was below specified trigger levels. The research found that the improvements in water supply reliabilities achieved by evaporation suppression did not decrease significantly with lower trigger levels. Thus, the economics of evaporation suppression can be significantly improved by applying suppression methods only during relatively infrequent periods of significant or perhaps severe draw-downs.

Recommendations for future studies are as follows. First there should be an effort to perform large scale evaporation suppression field studies on reservoirs of various sizes located in various regions of Texas. Past evaporation suppression studies reported in the literature provide a good overview on achievable evaporation reductions but many factors have changed. New evaporation suppression material has been invented, improved application techniques have been implemented in field experiments in various countries, and techniques for calculation of lake evaporation have been modified and improved. Performing additional field studies with alternative evaporation suppression technologies would be beneficial.

The second recommendation is that WRAP/WAM simulation studies be performed for individual reservoirs. Individual reservoirs vary greatly in size and physical configuration, climate and hydrology, water use, operating rules, and other characteristics. The basin wide evaporation suppression studies presented in this thesis contribute to an improved general understanding of the impact that reservoir evaporation and potential evaporation reductions have on water supply but detailed studies of individual reservoirs are required for in depth assessments. Plans controlling the timing of evaporation suppression based on storage triggers should be developed along with developing the evaporation suppression methods for a particular reservoir.

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APPENDIX A

RESERVOIR EVAPORATION/PRECIPITATION

QUADRANGLE EQUATIONS

Table A. 1 – Canadian River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
105	-	1.000 (105)
106	-	1.000 (106)
107	-	1.000 (107)
205	-	1.000 (205)
206	-	1.000 (206)
207	-	1.000 (207)
A10160	Lake Rita Blanca	0.426 (105) + 0.207 (106) + 0.367 (205)
B10130	Lake Meredith	0.139 (106) + 0.159 (205) + 0.577 (206) + 0.125 (207)
F10020	PaloDuro	0.127 (105) + 0.484 (106) + 0.236 (107) + 0.153 (206)

Table A. 2 – Red River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
205	-	1.000 (205)
206	-	1.000 (206)
207	-	1.000 (207)
305	-	1.000 (305)
306	-	1.000 (306)
307	-	1.000 (307)
308	-	1.000 (308)
309	-	0.406 (308) + 0.258 (408) + 0.336 (409)
406	-	1.000 (406)
407	-	1.000 (407)
408	-	1.000 (408)
409	-	1.000 (409)
410	-	1.000 (410)
411	-	1.000 (411)
412	-	1.000 (412)
413	-	1.000 (413)

Table A. 2 Continued – Red River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
10140	-	0.257 (206) + 0.373 (207) + 0.172 (306) + 0.197 (307)
B10060	Greenbelt	0.242 (206) + 0.275 (207) + 0.226 (306) + 0.257 (307)
C10080	Buffalo Lake	0.237 (205) + 0.200 (206) + 0.319 (305) + 0.244 (306)
C10210	Bivins	0.275 (205) + 0.246 (206) + 0.249 (305) + 0.230 (306)
D10130	Mackenzie	0.053 (206) + 0.058 (305) + 0.827 (306) + 0.062 (307)
D10030	Baylor Creek	0.072 (207) + 0.750 (307) + 0.101 (308) + 0.077 (407)
J10010	-	0.189 (307) + 308 (0.221) + 0.275 (407) + 0.315 (408)
N10020	Lake Kemp	0.199 (308) + 0.139 (407) + 0.433 (408) + 0.229 (409)
O10020	Lake Electra	0.250 (308) + 0.239 (309) + 0.261 (408) + 0.250 (409)
O10090	Santa Rosa Lake; Wharton Lake	0.283 (308) + 0.151 (407) + 0.350 (408) + 0.216 (409)
P10060	North Fork Buffalo Creek	0.198 (308) + 0.294 (309) + 0.198 (408) + 0.310 (409)
P10110	Lake Diversion	0.214 (309) + 0.307 (408) + 0.344 (409) + 0.135 (410)
Q10080	Lake Wichita	0.232 (309) + 0.175 (408) + 0.430 (409) + 0.163 (410)
R10010	Lake Kickapoo	0.140 (308) + 0.160 (309) + 0.237 (408) + 0.463 (409)
S10030	Lake Arrowhead	0.159 (309) + 0.133 (408) + 0.544 (409) + 0.164 (410)
V10020	Hubert H Moss Lake	0.127 (309) + 0.150 (409) + 0.485 (410) + 0.238 (411)
V10070	Lake Nocona	0.177 (309) + 0.210 (409) + 0.449 (410) + 0.164 (411)
W10020	Randall Lake	0.096 (309) + 0.200 (410) + 0.529 (411) + 0.175 (412)
W10060	Lake Texoma	0.120 (309) + 0.244 (410) + 0.450 (411) + 0.186 (412)
X10010	Pat Mayse	0.233 (411) + 0.573 (412) + 0.194 (413)
X10230	Coffee Mill Lake; Lake Fannin	0.161 (410) + 0.422 (411) + 0.417 (412)
X10270	Lake Bonham	0.156 (410) + 0.531 (411) + 0.313 (412)
X10490	Valley Lake	0.058 (309) + 0.120 (410) + 0.673 (411) + 0.149 (412)
Y10330	Lake Crook	0.191 (411) + 0.648 (412) + 0.161 (413)

Table A. 3 – Sulphur River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
D120	Lake Sulphur Springs	0.743 (412) + 0.257 (413)
A70	-	1.000 (411)
E60	-	1.000 (413)
F60	Wright Patman Lake	0.218 (412) + 0.782 (413)

Table A. 4 – Cypress Bayou Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
A10340	Lake Cypress Springs	0.319 (412) + 0.225 (413) + 0.265 (512) + 0.191 (513)
A10240	Monticello	0.304 (412) + 0.265 (413) + 0.233 (512) + 0.199 (513)
A10200	Lake Bob Sandlin	0.289 (412) + 0.253 (413) + 0.249 (512) + 0.209 (513)
B10270	Welsh	0.289 (412) + 0.253 (413) + 0.249 (512) + 0.209 (513)
B10170	Ellison Creek	0.187 (412) + 0.273 (413) + 0.204 (512) + 0.336 (513)
B10070	Johnson Creek	0.160 (412) + 0.253 (413) + 0.188 (512) + 0.398 (513)
F10005	Caddo Lake	0.337 (413) + 0.663 (513)
QAD412	-	1.000 (412)
QAD413	-	1.000 (413)
QAD512	-	1.000 (512)
QAD513	-	1.000 (513)

Table A. 5 – Rio Grande River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
CT1160	Amistad Reservoir	0.147 (706) + 0.138 (707) + 0.426 (806) + 0.289 (807)
DT1001	Falcon Reservoir	0.214 (1008) + 0.532 (1108) + 0.253 (1109)
GT3010	Red Bluff Reservoir	0.472 (603) + 0.528 (604)

Table A. 6 – Colorado River Basin and Brazos-Colorado Coastal

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
A10010	-	1.000 (507)
A30060	Lake J.B. Thomas	0.025 (406) + 0.663 (506) + 0.312 (507)
A30010	-	1.000 (506)
B10050	E.V. Spence Reservoir	0.420 (507) + 0.580 (607)
B10010	-	1.000 (607)
B20020	Lake Colorado City	0.383 (506) + 0.537 (507) + 0.080 (607)
B30340	Sulphur Springs Draw	0.214 (505) + 0.653 (506) + 0.133 (606)
B30280	-	1.000 (605)
B30170	Red Draw Dam	0.671 (506) + 0.081 (507) + 0.248 (606)
B30010	Mitchell Co. Reservoir	0.491 (506) + 0.318 (507) + 0.150 (606) + 0.041 (607)
B40000	Champion Creek Reservoir	0.311 (506) + 0.555 (507) + 0.134 (607)
C10020	-	1.000 (608)
C20330	Twin Buttes Reservoir	0.029 (606) + 0.835 (607) + 0.136 (707)
C20260	Lake Nasworthy	0.877 (607) + 0.003 (608) + 0.120 (707)
C20040	O.C. Fisher Lake	0.990 (607) + 0.010 (707)
C70030	-	1.000 (606)
D20050	O.H. Ivie Reservoir	0.024 (508) + 0.166 (607) + 0.810 (608)
D30450	Lake Winters	0.136 (507) + 0.288 (508) + 0.202 (607) + 0.374 (608)
D30300	-	1.000 (508)
D40620	Oak Creek Reservoir	0.455 (507) + 0.100 (508) + 0.387 (607) + 0.058 (608)
D40040	Ballinger Municipal Lake	0.099 (507) + 0.054 (508) + 0.461 (607) + 0.386 (608)
E10010	-	1.000 (609)
E20090	Brady Creek Reservoir	0.616 (608) + 0.038 (609) + 0.346 (708)
E30010	-	1.000 (708)
E40460	-	1.000 (707)
F31170	Lake Clyde	0.026 (507) + 0.683 (508) + 0.291 (608)
F30420	Lake Coleman	0.530 (508) + 0.470 (608)
F30370	Hords Creek Lake	0.349 (508) + 0.003 (607) + 0.648 (608)
F30130	Lake Brownwood	0.162 (508) + 0.141 (509) + 0.363 (608) + 0.334 (609)
G10010	-	1.000 (709)
I10340	Lake Austin	0.246 (709) + 0.637 (710) + 0.117 (810)
I10001	-	1.000 (710)
I21280	Inks Lake	0.229 (609) + 0.689 (709) + 0.082 (710)
I20820	Lake LBJ	0.057 (609) + 0.811 (709) + 0.132 (710)
I20590	Lake Marble Falls	0.029 (609) + 0.777 (709) + 0.194 (710)

Table A. 6 Continued – Colorado River Basin and Brazos-Colorado Coastal

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
I20000	Lake Travis	0.410 (709) + 0.590 (710)
I40000	Lake Buchanan	0.283 (609) + 0.692 (709) + 0.025 (710)
J10220	-	1.000 (810)
J10121	Lake Fayette	0.036 (710) + 0.348 (711) + 0.124 (810) + 0.492 (811)
J10040	-	1.000 (711)
J10020	-	1.000 (811)
J30330	Decker Lake	0.068 (709) + 0.732 (710) + 0.200 (810)
J30030	Lake Bastrop	0.571 (710) + 0.130 (711) + 0.299 (810)
K10040	-	0.261 (811) + 0.347 (812) + 0.393 (911)
K10020	-	1.000 (911)
K20050	Eagle Lake	0.051 (711) + 0.799 (811) + 0.150 (812)
L10010	-	1.000 (812)
M10020	STP Main Cooling Reservoir	0.124 (811) + 0.081 (812) + 0.431 (911) + 0.364 (912)

Table A. 7 – Brazos River Basin and San Jacinto-Brazos Coastal

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
366631	-	1.000 (305)
368131	-	1.000 (306)
368931	-	1.000 (406)
369331	White River	0.589 (406) + 0.411 (407)
370431	-	1.000 (405)
370631	Buffalo Springs	0.097 (305) + 0.115 (306) + 0.170 (405) + 0.618 (507)
371131	-	1.000 (406)
371431	-	1.000 (812)
4146P1	Alan Henry	0.097 (305) + 0.115 (306) + 0.170 (405) + 0.618 (507)
372031	-	1.000 (506)
341131	-	1.000 (407)
341331	-	1.000 (408)
344031	Davis	0.267 (407) + 0.733 (408)
344431	Millers Creek	0.708 (408) + 0.118 (409) + 0.098 (508) + 0.076 (509)
344801	-	1.000 (409)

Table A. 7 Continued – Brazos River Basin and San Jacinto-Brazos Coastal

417931	Stamford	0.188 (407) + 0.339 (408) + 0.176 (507) + 0.297 (508)
413031	Sweetwater	0.634 (507) + 0.158 (508) + 0.114 (607) + 0.094 (608)
413331	-	1.000 (507)
414231	Abilene	0.277 (507) + 0.364 (508) + 0.175 (607) + 0.184 (608)
415031	Kriby	0.193 (507) + 0.550 (508) + 0.116 (607) + 0.141 (608)
416131	Fort Phantom Hill	0.104 (407) + 0.126 (408) + 0.168 (507) + 0.602 (508)
421131	Cisco	0.188 (407) + 0.339 (408) + 0.176 (507) + 0.297 (508)
421331	Hubbard	0.194 (408) + 0.194 (409) + 0.299 (508) + 0.313 (509)
421431	Daniel	0.141 (408) + 0.158 (409) + 0.255 (508) + 0.446 (509)
345831	Graham	0.194 (408) + 0.410 (409) + 0.159 (508) + 0.237 (509)
515531	Possum Kingdom	0.386 (409) + 0.614 (509)
403131	Palo Pinto	0.136 (409) + 0.108 (410) + 0.586 (509) + 0.170 (510)
403931	Mineral Wells	0.206 (409) + 0.195 (410) + 0.312 (509) + 0.287 (510)
515631	Granbury	0.200 (509) + 0.556 (510) + 0.112 (609) + 0.132 (610)
409731	Squaw Creek	0.217 (509) + 0.468 (510) + 0.142 (609) + 0.173 (610)
410631	Pat Cleburn	0.577 (510) + 0.154 (511) + 0.157 (610) + 0.112 (611)
515731	Whitney	0.296 (510) + 0.169 (511) + 0.355 (610) + 0.180 (611)
515831	Aquilla	0.262 (510) + 0.196 (511) + 0.321 (610) + 0.211 (611)
220131	-	1.000 (508)
225331	-	1.000 (510)
227031	-	1.000 (509)
228731	-	1.000 (609)
231531	Waco	0.138 (510) + 0.119 (511) + 0.528 (608) + 0.215 (611)
347031	Leon	0.265 (508) + 0.420 (509) + 0.150 (608) + 0.165 (609)
515931	Proctor	0.511 (509) + 0.489 (609)
293631	Belton	0.171 (609) + 0.421 (610) + 0.151 (709) + 0.257 (710)
299231	-	1.000 (611)
516131	Stillhouse Hollow	0.174 (609) + 0.329 (610) + 0.168 (709) + 0.329 (710)
516231	Georgetown	0.128 (609) + 0.158 (610) + 0.200 (709) + 0.514 (710)
516331	Granger	0.157 (610) + 0.117 (611) + 0.557 (710) + 0.169 (711)
375931	-	1.000 (710)
434231	Tradinghouse Creek	0.480 (610) + 0.520 (611)
434531	Lake Creek	0.480 (610) + 0.520 (611)
435533	Marlin City	1.000 (611)
406331	-	1.000 (610)
526831	Bryan Utilities	1.000 (711)
527231	Alcoa	0.154 (610) + 0.146 (611) + 0.391 (710) + 0.309 (711)

Table A. 7 Continued – Brazos River Basin and San Jacinto-Brazos Coastal

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
554032	Sandow Surface Mine	1.000 (710)
516431	Somerville	0.150 (710) + 0.592 (711) + 0.108 (810) + 0.150 (811)
528731	Mexia	0.065 (510) + 0.086 (511) + 0.094 (610) + 0.755 (611)
516531	Limestone	0.655 (611) + 0.143 (611) + 0.113 (711) + 0.089 (712)
529831	Twin Oaks	0.724 (611) + 0.276 (711)
530131	Camp Creek	0.337 (611) + 0.197 (612) + 0.284 (711) + 0.182 (712)
531131	Gibbons Creek	0.169 (611) + 0.162 (612) + 0.359 (711) + 0.310 (712)
531531	-	1.000 (712)
292531	Allen Creek	1.000 (811)
532841	William Harris	1.000 (812)
549231	Eagle Nest	1.000 (812)
532842	Brazoria	1.000 (812)
532531	Smithers	0.144 (811) + 0.856 (812)
401041	-	1.000 (812)
516841	-	1.000 (813)

Table A. 8 – Trinity River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
B3313B	Lost Creek	0.386 (409) + 0.247 (410) + 0.197 (509) + 0.171 (510)
B3808A	Bridgeport	0.256 (409) + 0.367 (410) + 0.174 (509) + 0.203 (510)
B3320B	Amon Carter	0.419 (409) + 0.581 (410)
B3809A	Eagle Mountain	0.384 (410) + 0.616 (510)
B3340A	Worth	0.306 (410) + 0.694 (510)
B3356A	Weatherford	0.145 (409) + 0.192 (410) + 0.201 (509) + 0.463 (510)
B5157P	Benbrook	1.000 (510)
B3391A	Arlington	0.175 (410) + 0.147 (411) + 0.448 (510) + 0.230 (511)
B3404A	Joe Pool	0.157 (410) + 0.155 (411) + 0.347 (510) + 0.340 (511)
B3408A	Mountain Creek	0.159 (410) + 0.179 (411) + 0.312 (510) + 0.350 (511)
B2334A	Kiowa	0.528 (410) + 0.472 (411)

Table A. 8 Continued – Trinity River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
B2335A	Ray Roberts	0.402 (410) + 0.309 (411) + 0.147 (510) + 0.142 (511)
B2456A	Lewisville	0.277 (410) + 0.286 (411) + 0.216 (510) + 0.221 (511)
B2362A	Grapevine	0.269 (410) + 0.226 (411) + 0.274 (510) + 0.231 (511)
B2365A	North	0.250 (410) + 0.250 (411) + 0.250 (510) + 0.250 (511)
B2461A	White Rock	0.167 (410) + 0.221 (411) + 0.211 (510) + 0.400 (511)
B2410A	Lavon	0.561 (411) + 0.439 (511)
B2462A	Ray Hubbard	0.366 (411) + 0.634 (511)
B4972A	Terrell	0.185 (411) + 0.417 (511) + 0.156 (412) + 0.242 (512)
B4983A	Forest Grove	0.289 (511) + 0.340 (512) + 0.181 (611) + 0.190 (612)
B4976A	Cedar Creek	0.415 (511) + 0.252 (512) + 0.179 (611) + 0.155 (612)
B5018A	Waxahachie	0.240 (510) + 0.456 (511) + 0.141 (610) + 0.163 (611)
B5021A	Bardwell	0.185 (510) + 0.508 (511) + 0.131 (610) + 0.175 (611)
B5030A	Halbert	0.574 (511) + 0.426 (611)
B4992A	Navarro Mills	0.193 (510) + 0.268 (511) + 0.212 (610) + 0.327 (611)
B5035A	Richland-Chambers	0.281 (511) + 0.207 (512) + 0.300 (611) + 0.212 (612)
B5040A	Fairfield	0.204 (511) + 0.194 (512) + 0.316 (611) + 0.286 (612)
B5097A	Houston County	0.123 (611) + 0.695 (612) + 0.079 (711) + 0.103 (712)
B4248B	Livingston	0.181 (612) + 0.164 (613) + 0.382 (712) + 0.273 (713)
B4279C	Anahuac	0.161 (712) + 0.227 (713) + 0.205 (812) + 0.407 (813)
EV409	-	1.000 (409)
EV410	-	1.000 (410)
EV411	-	1.000 (411)
EV412	-	1.000 (412)
EV509	-	1.000 (509)
EV510	-	1.000 (510)
EV511	-	1.000 (511)
EV512	-	1.000 (512)
EV610	-	1.000 (610)
EV611	-	1.000 (611)
EV612	-	1.000 (612)
EV613	-	1.000 (613)
EV711	-	1.000 (711)
EV712	-	1.000 (712)
EV713	-	1.000 (713)
EV714	-	1.000 (714)

Table A. 8 Continued – Trinity River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
EV812	-	1.000 (812)
EV813	-	1.000 (813)
EV814	-	0.260 (713) + 0.345 (714) + 0.394 (813)

Table A. 9 – Neches River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
3256N	Athens Lake	0.555 (512) + 0.180 (513) + 0.265 (612)
3254N1	Lake Palestine	0.463 (512) + 0.165 (513) + 0.188 (612) + 0.184 (613)
3274N2	Lake Jacksonville	0.265 (512) + 0.180 (513) + 0.354 (612) + 0.201 (613)
4853A	Lake Tyler	0.389 (512) + 0.251 (513) + 612 (0.193) + 0.166 (613)
4537A	-	1.000 (612)
4847A	Lake Striker	0.237 (512) + 0.241 (513) + 0.258 (612) + 0.263 (613)
4864A	Lake Nacogdoches	0.134 (512) + 0.153 (513) + 0.239 (612) + 0.474 (613)
4393A1	Lake Kurth	0.088 (512) + 0.104 (513) + 0.160 (612) + 0.647 (613)
5585A	-	1.000 (613)
4404A	Pinkston Reservoir	0.122 (512) + 0.192 (513) + 0.153 (612) + 0.533 (613)
4411A1	Sam Rayburn Reservoir	0.178 (612) + 0.558 (613) + 0.264 (713)
4411N2	B.A. Steinhagen Lake	0.173 (612) + 0.321 (613) + 0.506 (713)

Table A. 10 – Sabine River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
E4642A	Lake Cherokee	1.000 (513)
E4647A	Brandy Branch	1.000 (513)
E4649A	Martin Lake	1.000 (513)
E4654A	Lake Murvaul	0.556 (513) + 0.444 (613)
E4658A	Toledo Bend	1.000 (614)
E4669A	Lake Fork	0.209 (412) + 0.791 (512)

Table A. 10 Continued – Sabine River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
E4670A	Lake Tawakoni	0.182 (411) + 0.205 (412) + 0.277 (511) + 0.336 (512)
E4690A	Lake Holbrook	1.000 (512)
E4708A	Lake Quitman	0.293 (412) + 0.707 (512)
A4736A	Lake Hawkins	1.000 (512)
E4749A	Lake Winnsboro	0.374 (412) + 0.626 (512)
E4762A	Lake Gladewater	0.456 (512) + 0.544 (513)
EV411	-	1.000 (411)
EV412	-	1.000 (412)
EV511	-	1.000 (511)
EV512	-	1.000 (512)
EV513	-	1.000 (513)
EV613	-	1.000 (613)
EV614	-	1.000 (614)
EV714	-	1.000 (714)

Table A. 11 – Nueces River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
246501	-	1.000 (910)
302201	-	1.000 (807)
302501	-	1.000 (808)
308031	-	1.000 (908)
308801	-	1.000 (907)
314201	-	1.000 (909)
320701	-	1.000 (809)
CP27	Choke Canyon Reservoir	0.128 (908) + 0.872 (909)
CP30	Lake Corpus Christi	0.446 (909) + 0.554 (910)
CP31	-	0.387 (713) + 0.613 (813)

Table A. 12 – Guadalupe and San Antonio River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
114201	-	1.000 (809)
116302	-	1.000 (810)
193031	-	1.000 (708)
194131	-	1.000 (808)
205601	-	1.000 (709)
207401	Canyon Lake	0.247 (709) + 0.180 (710) + 0.362 (809) + 0.211 (810)
216131	Victor Brauning Lake	0.136 (808) + 0.512 (809) + 0.171 (810) + 0.181 (909)
219131	-	1.000 (909)
374731	-	1.000 (710)
386041	-	1.000 (910)
548631	Colet Creek	0.490 (810) + 0.228 (910) + 0.282 (911)
213002	Medina Lake	0.148 (708) + 0.153 (709) + 0.320 (808) + 0.379 (809)

Table A. 13 – Lavaca River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
GS400	-	1.000 (811)
GS300	-	1.000 (911)
GS600	-	1.000 (811)
GS550	-	1.000 (811)
GS1000	-	1.000 (811)
GS500	-	0.367 (810) + 0.433 (811) + 0.200 (911)
WGS800	-	1.000 (811)

Table A. 14 – San Jacinto River Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
A4963A	Lake Conroe	0.898 (712) + 0.102 (812)
A4964A	Lake Houston	0.493 (712) + 0.507 (812)
A3995A	Sheldon Reservoir	0.402 (712) + 0.598 (812)
1006	-	0.364 (712) + 0.636 (812)

Table A. 15 – Lower Nueces-Rio Grande Coastal Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
1210	-	0.426 (1109) + 0.574 (1110)
1110	-	1.000 (1110)
1109	-	1.000 (1109)

Table A. 16 – Upper Nueces-Rio Grande Coastal Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
1009	-	1.000 (1009)
1010	-	1.000 (1010)

Table A. 17 – San Antonio-Nueces Coastal Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
910	-	1.000 (910)
911	-	1.000 (911)
1010	-	1.000 (1010)

Table A. 18 – Colorado-Lavaca Coastal Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
GS1300	-	0.354 (811) + 0.646 (911)

Table 19 – A. Trinity-San Jacinto Coastal Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
EV712	-	1.000 (712)
EV812	-	1.000 (812)
EV813	-	1.000 (813)

Table 20 – A. Neches-Trinity Coastal Basin

CP ID	Reservoir Name	Equations for Average Evap/Precip Using Data from Quadrangles
D4493A	J.D. Murphiree Impoundment	0.384 (713) + 0.616 (813)
EV813	-	1.000 (813)
EV713	-	1.000 (713)
EV814	-	0.398 (713) + 0.602 (813)

APPENDIX B

WRAP-SIME EVAPORATION SUPPRESSION RESULTS

Table B. 1
Canadian River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	73,267	67,143	57,823	41,174	0
reservoir precipitation (+)	22,891	23,356	24,107	25,706	30,494
water supply diversions (−)	120,859	126,045	133,225	144,715	163,603
return flows (+)	110,630	115,621	122,545	133,627	150,992
naturalized flow inflow (+)	225,937	225,937	225,937	225,937	225,937
regulated flow outflow (−)	111,830	116,821	123,745	134,826	152,191
change in storage (+)	10,543	10,490	10,431	10,324	6,591
other flows (+)	-64,045	-65,395	-68,226	-74,879	-98,220
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	165,195	165,193	165,192	165,170	165,076
shortage (acre-feet/year)	44,335	39,148	31,966	20,455	1,473
volume reliability (percent)	73.16%	76.30%	80.65%	87.62%	99.11%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	964,775	965,481	965,640	965,987	966,170
mean (acre-feet)	539,952	551,685	579,548	640,754	814,901
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	38.72	39.58	40.48	41.19	54.69
99%	39.99	40.43	40.96	41.37	58.17
98%	40.48	40.86	41.23	41.59	58.88
95%	41.10	41.29	41.65	41.66	60.68
90%	41.61	41.66	41.68	41.92	63.84
80%	41.87	42.21	42.95	44.49	69.90
70%	42.94	43.46	44.37	46.86	74.59
60%	45.22	45.94	48.12	57.50	82.31
50%	48.57	50.95	56.96	68.63	88.71
40%	53.19	55.59	61.51	73.41	92.34
30%	58.63	60.94	66.36	78.87	95.51
20%	69.53	72.55	77.13	86.43	97.65
10%	88.80	89.79	91.73	95.26	99.49

Table B. 2
Canadian River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	73,267	66,710	56,572	39,285	0
reservoir precipitation (+)	22,891	23,218	23,601	24,581	26,370
water supply diversions (−)	120,859	125,398	132,205	142,286	158,586
return flows (+)	110,630	114,999	121,593	131,384	146,858
naturalized flow inflow (+)	225,937	225,937	225,937	225,937	225,937
regulated flow outflow (−)	111,830	116,199	122,793	132,584	148,058
change in storage (+)	10,543	10,490	10,433	10,327	9,295
other flows (+)	-64,045	-66,338	-69,994	-78,075	-101,816
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	165,195	165,194	165,193	165,185	165,178
shortage (acre-feet/year)	44,335	39,796	32,988	22,899	6,592
volume reliability (percent)	73.16%	75.91%	80.03%	86.14%	96.01%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	964,775	965,425	965,556	965,784	965,970
mean (acre-feet)	539,952	546,674	559,714	595,118	652,637
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	38.72	39.47	40.45	41.16	41.78
99%	39.99	40.42	40.92	41.36	41.81
98%	40.48	40.75	41.20	41.57	41.97
95%	41.10	41.28	41.63	41.66	42.90
90%	41.61	41.66	41.67	41.90	45.68
80%	41.87	42.14	42.59	43.77	49.49
70%	42.94	43.37	44.09	45.54	56.33
60%	45.22	45.63	47.13	52.14	62.20
50%	48.57	49.92	53.02	60.29	68.85
40%	53.19	54.61	57.39	64.38	72.43
30%	58.63	59.70	62.66	69.00	75.89
20%	69.53	70.77	71.65	75.75	83.18
10%	88.80	89.10	89.62	91.91	92.69

Table B. 3
Canadian River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	73,267	66,316	55,614	37,462	0
reservoir precipitation (+)	22,891	23,098	23,235	23,467	24,054
water supply diversions (−)	120,859	123,942	128,580	135,820	147,994
return flows (+)	110,630	113,569	118,056	125,048	136,722
naturalized flow inflow (+)	225,937	225,937	225,937	225,937	225,937
regulated flow outflow (−)	111,830	114,769	119,255	126,248	137,922
change in storage (+)	10,543	10,509	10,482	10,441	10,245
other flows (+)	-64,045	-68,086	-74,261	-85,363	-111,043
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	165,195	165,194	165,194	165,193	165,192
shortage (acre-feet/year)	44,335	41,253	36,614	29,374	17,198
volume reliability (percent)	73.16%	75.03%	77.84%	82.22%	89.59%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	964,775	965,077	965,455	965,543	965,646
mean (acre-feet)	539,952	542,257	545,505	550,599	561,015
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	38.72	39.41	40.45	41.17	41.71
99%	39.99	40.44	40.92	41.37	41.73
98%	40.48	40.72	41.14	41.53	41.75
95%	41.10	41.29	41.56	41.66	41.79
90%	41.61	41.67	41.67	41.75	42.80
80%	41.87	42.04	42.37	43.15	44.60
70%	42.94	43.23	43.71	44.33	45.83
60%	45.22	45.41	45.71	46.44	48.18
50%	48.57	48.94	49.28	49.87	51.20
40%	53.19	53.36	53.96	54.52	55.61
30%	58.63	58.92	59.07	59.76	61.37
20%	69.53	69.69	69.95	70.45	71.24
10%	88.80	89.02	89.18	89.20	89.40

Table B. 4
Canadian River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	73,267	65,977	55,036	36,773	0
reservoir precipitation (+)	22,891	22,903	22,924	22,971	23,173
water supply diversions (−)	120,859	120,903	120,967	121,069	121,328
return flows (+)	110,630	110,630	110,630	110,630	110,630
naturalized flow inflow (+)	225,937	225,937	225,937	225,937	225,937
regulated flow outflow (−)	111,830	111,830	111,830	111,830	111,830
change in storage (+)	10,543	10,542	10,540	10,537	10,522
other flows (+)	-64,045	-71,303	-82,197	-100,403	-137,104
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	165,195	165,194	165,194	165,194	165,194
shortage (acre-feet/year)	44,335	44,292	44,227	44,126	43,866
volume reliability (percent)	73.16%	73.19%	73.23%	73.29%	73.45%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	964,775	964,780	964,791	964,820	964,862
mean (acre-feet)	539,952	540,063	540,260	540,618	541,804
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	38.72	38.80	38.92	39.09	39.56
99%	39.99	40.05	40.16	40.27	40.35
98%	40.48	40.49	40.52	40.59	40.78
95%	41.10	41.10	41.10	41.13	41.23
90%	41.61	41.61	41.62	41.64	41.71
80%	41.87	41.88	41.91	41.99	42.08
70%	42.94	42.96	42.97	42.99	43.17
60%	45.22	45.22	45.22	45.23	45.27
50%	48.57	48.57	48.58	48.59	48.62
40%	53.19	53.19	53.19	53.20	53.25
30%	58.63	56.63	58.65	58.75	58.80
20%	69.53	69.53	69.53	69.57	69.73
10%	88.80	88.84	88.91	89.00	89.18

Table B. 5
Red River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	616,551	570,428	491,543	346,553	0
reservoir precipitation (+)	403,041	412,122	422,047	438,462	464,174
water supply diversions (−)	1,029,069	1,030,874	1,034,115	1,039,373	1,049,463
return flows (+)	126,743	126,843	126,975	127,250	131,556
naturalized flow inflow (+)	3,112,338	3,112,338	3,112,338	3,112,338	3,112,338
regulated flow outflow (−)	2,138,901	2,185,827	2,261,072	2,398,625	2,728,313
change in storage (+)	18,843	17,065	14,642	11,032	5,171
other flows (+)	123,554	118,761	110,727	95,469	64,537
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,160,702	1,159,677	1,157,672	1,153,622	1,137,536
shortage (acre-feet/year)	131,633	128,803	123,557	114,249	88,073
volume reliability (percent)	88.66%	88.89%	89.33%	90.10%	92.26%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,006,230	4,008,606	4,012,162	4,017,989	4,029,306
mean (acre-feet)	3,317,959	3,384,140	3,477,906	3,643,673	3,894,432
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	58.16	61.17	66.11	73.98	85.15
99%	63.95	67.26	71.61	78.06	87.18
98%	68.33	68.31	72.90	79.25	88.60
95%	68.70	71.25	74.49	81.52	90.89
90%	70.47	73.13	76.73	83.56	92.79
80%	76.55	78.73	81.66	86.33	94.96
70%	80.00	81.72	84.35	88.70	96.10
60%	82.25	84.03	86.35	90.55	96.83
50%	84.09	85.48	88.06	92.12	97.55
40%	85.72	87.14	89.27	92.89	98.06
30%	87.07	88.46	90.55	93.79	98.39
20%	89.45	90.27	91.73	94.64	98.71
10%	92.05	92.70	93.63	95.87	99.19

Table B. 6
Red River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	616,551	563,804	480,339	332,161	0
reservoir precipitation (+)	403,041	408,003	415,046	426,981	448,710
water supply diversions (−)	1,029,069	1,030,270	1,032,161	1,035,245	1,039,212
return flows (+)	126,743	126,823	126,856	126,955	127,195
naturalized flow inflow (+)	3,112,338	3,112,338	3,112,338	3,112,338	3,112,338
regulated flow outflow (−)	2,138,901	2,141,258	2,146,179	2,153,985	2,171,188
change in storage (+)	18,843	18,412	17,829	16,510	13,838
other flows (+)	123,554	69,754	-13,390	-161,393	-491,681
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,160,702	1,160,128	1,159,350	1,157,424	1,154,075
shortage (acre-feet/year)	131,633	129,858	127,189	122,180	114,863
volume reliability (percent)	88.66%	88.81%	89.03%	89.44%	90.05%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,006,230	4,006,232	4,006,235	4,006,239	4,006,250
mean (acre-feet)	3,317,959	3,346,738	3,387,957	3,464,149	3,593,898
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	58.16	58.60	59.41	61.14	65.45
99%	63.95	64.99	66.13	68.33	71.96
98%	68.33	66.01	67.11	69.36	73.36
95%	68.70	69.54	70.72	73.31	78.18
90%	70.47	71.63	73.12	75.95	80.49
80%	76.55	77.49	78.78	81.07	84.75
70%	80.00	80.72	82.03	84.06	87.60
60%	82.25	82.96	84.50	86.46	89.76
50%	84.09	84.91	86.15	88.21	91.17
40%	85.72	86.34	87.43	89.26	92.44
30%	87.07	87.70	88.84	90.59	93.54
20%	89.45	89.61	90.33	92.12	94.78
10%	92.05	92.39	92.88	94.04	96.19

Table B. 7
Red River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	616,551	558,270	469,505	318,735	0
reservoir precipitation (+)	403,041	404,606	406,842	412,273	419,331
water supply diversions (−)	1,029,069	1,029,862	1,031,047	1,032,935	1,037,659
return flows (+)	126,743	126,779	126,823	126,865	127,007
naturalized flow inflow (+)	3,112,338	3,112,338	3,112,338	3,112,338	3,112,338
regulated flow outflow (−)	2,138,901	2,139,176	2,140,796	2,143,281	2,146,995
change in storage (+)	18,843	18,756	18,615	18,030	16,894
other flows (+)	123,554	64,828	-23,269	-174,555	-490,915
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,160,702	1,160,341	1,159,785	1,158,792	1,156,033
shortage (acre-feet/year)	131,633	130,479	128,738	125,857	118,374
volume reliability (percent)	88.66%	88.76%	88.90%	89.14%	89.76%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,006,230	4,006,230	4,006,230	4,006,229	4,006,229
mean (acre-feet)	3,317,959	3,329,191	3,348,027	3,384,997	3,440,634
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	58.16	58.33	58.65	59.28	60.33
99%	63.95	64.48	64.96	65.71	67.07
98%	68.33	65.59	65.99	66.86	67.98
95%	68.70	69.15	69.55	70.85	72.35
90%	70.47	70.97	71.73	72.74	74.77
80%	76.55	76.87	77.38	78.62	80.19
70%	80.00	80.26	80.85	82.08	83.17
60%	82.25	82.54	83.05	84.30	85.80
50%	84.09	84.53	85.02	86.05	87.40
40%	85.72	85.98	86.36	87.31	88.68
30%	87.07	87.27	87.65	88.62	89.88
20%	89.45	89.52	89.61	90.16	91.59
10%	92.05	92.22	92.49	93.22	94.24

Table B. 8
Red River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	616,551	556,063	464,907	311,545	0
reservoir precipitation (+)	403,041	403,551	404,313	405,448	405,019
water supply diversions (−)	1,029,069	1,029,395	1,030,095	1,031,292	1,033,619
return flows (+)	126,743	126,759	126,787	126,810	126,859
naturalized flow inflow (+)	3,112,338	3,112,338	3,112,338	3,112,338	3,112,338
regulated flow outflow (−)	2,138,901	2,138,322	2,138,533	2,138,927	2,139,038
change in storage (+)	18,843	18,817	18,763	18,484	18,203
other flows (+)	123,554	62,316	-28,666	-181,317	-489,762
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,160,702	1,160,502	1,160,206	1,159,672	1,158,691
shortage (acre-feet/year)	131,633	131,107	130,110	128,380	125,072
volume reliability (percent)	88.66%	88.70%	88.79%	88.93%	89.21%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,006,230	4,006,230	4,006,230	4,006,229	4,006,229
mean (acre-feet)	3,317,959	3,321,142	3,326,107	3,335,621	3,338,651
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	58.16	58.17	58.19	58.21	57.91
99%	63.95	64.12	64.32	64.57	64.14
98%	68.33	65.39	65.47	65.56	65.64
95%	68.70	68.84	68.98	69.01	68.80
90%	70.47	70.61	70.75	70.94	70.94
80%	76.55	76.68	76.80	77.02	76.90
70%	80.00	80.07	80.19	80.58	80.64
60%	82.25	82.32	82.42	82.62	82.96
50%	84.09	84.23	84.44	84.70	84.69
40%	85.72	85.81	85.95	86.16	86.07
30%	87.07	87.15	87.25	87.48	87.61
20%	89.45	89.48	89.52	89.70	89.92
10%	92.05	92.10	92.22	92.45	92.95

Table B. 9
Sulphur River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	218,858	198,967	167,410	113,100	0
reservoir precipitation (+)	219,301	221,289	223,104	225,650	229,418
water supply diversions (−)	375,975	376,504	377,049	377,441	378,088
return flows (+)	566	568	570	570	570
naturalized flow inflow (+)	2,590,599	2,590,599	2,590,599	2,590,599	2,590,599
regulated flow outflow (−)	2,214,737	2,235,524	2,267,627	2,322,768	2,435,063
change in storage (+)	969	647	286	130	138
other flows (+)	-1,865	-2,108	-2,472	-3,640	-7,574
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	380,546	380,544	380,541	380,519	380,464
shortage (acre-feet/year)	4,571	4,040	3,492	3,078	2,376
volume reliability (percent)	98.80%	98.94%	99.08%	99.19%	99.38%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	757,151	757,155	757,158	757,158	757,158
mean (acre-feet)	614,168	620,845	629,941	642,852	662,474
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	37.09	39.41	43.47	51.63	65.24
99%	42.05	44.94	49.62	57.67	71.00
98%	50.11	53.12	56.86	63.81	72.27
95%	59.84	62.33	64.89	68.57	75.32
90%	65.79	67.60	69.56	73.05	78.20
80%	71.84	73.36	75.00	77.57	82.24
70%	76.21	77.63	79.26	81.41	83.88
60%	79.83	80.61	81.79	83.56	83.94
50%	83.00	83.38	83.87	83.94	85.52
40%	83.91	83.94	84.74	86.09	88.60
30%	87.07	87.91	88.71	90.46	91.85
20%	91.79	91.85	91.86	92.72	95.47
10%	97.95	98.19	98.91	99.11	99.79

Table B. 10
Sulphur River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	218,858	197,551	165,100	110,539	0
reservoir precipitation (+)	219,301	219,917	220,510	221,408	222,862
water supply diversions (−)	375,975	376,205	376,497	376,830	377,211
return flows (+)	566	566	568	570	570
naturalized flow inflow (+)	2,590,599	2,590,599	2,590,599	2,590,599	2,590,599
regulated flow outflow (−)	2,214,737	2,219,904	2,227,626	2,240,298	2,264,975
change in storage (+)	969	802	587	279	124
other flows (+)	-1,865	-18,225	-43,041	-85,188	-171,969
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	380,546	380,546	380,546	380,537	380,537
shortage (acre-feet/year)	4,571	4,341	4,049	3,707	3,326
volume reliability (percent)	98.80%	98.86%	98.94%	99.03%	99.13%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	757,151	757,152	757,154	757,156	757,157
mean (acre-feet)	614,168	615,973	618,569	622,637	629,008
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	37.09	38.22	39.96	43.46	52.07
99%	42.05	44.19	47.42	51.29	57.72
98%	50.11	51.63	53.81	57.00	61.87
95%	59.84	60.54	61.71	63.79	66.34
90%	65.79	66.32	66.99	67.97	70.21
80%	71.84	72.32	72.78	73.47	74.99
70%	76.21	76.44	76.85	77.47	78.32
60%	79.83	79.92	80.33	80.90	81.34
50%	83.00	83.09	83.27	83.55	83.78
40%	83.91	83.92	83.92	83.94	84.35
30%	87.07	87.12	87.27	87.51	87.61
20%	91.79	91.81	91.81	91.85	91.86
10%	97.95	97.99	98.04	98.12	98.40

Table B. 11
Sulphur River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	218,858	197,039	164,278	109,604	0
reservoir precipitation (+)	219,301	219,386	219,498	219,685	220,023
water supply diversions (−)	375,975	376,055	376,167	376,328	376,590
return flows (+)	566	566	566	566	568
naturalized flow inflow (+)	2,590,599	2,590,599	2,590,599	2,590,599	2,590,599
regulated flow outflow (−)	2,214,737	2,215,026	2,215,447	2,216,168	2,217,661
change in storage (+)	969	922	851	687	421
other flows (+)	-1,865	-23,353	-55,621	-109,438	-217,360
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	380,546	380,546	380,546	380,546	380,546
shortage (acre-feet/year)	4,571	4,491	4,379	4,218	3,956
volume reliability (percent)	98.80%	98.82%	98.85%	98.89%	98.96%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	757,151	757,151	757,152	757,153	757,156
mean (acre-feet)	614,168	614,437	614,843	615,541	616,805
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	37.09	37.40	37.81	38.50	40.72
99%	42.05	42.49	43.14	43.69	45.30
98%	50.11	5035.00	50.70	51.26	52.20
95%	59.84	59.96	60.08	60.70	61.50
90%	65.79	65.80	65.82	66.04	66.08
80%	71.84	71.87	71.96	72.00	72.11
70%	76.21	76.26	76.33	76.40	76.56
60%	79.83	79.86	79.92	79.96	80.14
50%	83.00	83.01	83.03	83.10	83.25
40%	83.91	83.91	83.91	83.92	83.93
30%	87.07	87.09	87.12	87.18	87.27
20%	91.79	91.80	91.82	91.83	91.83
10%	97.95	97.97	98.00	98.03	98.04

Table B. 12
Sulphur River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	218,858	196,990	164,166	109,459	0
reservoir precipitation (+)	219,301	219,318	219,340	219,374	219,445
water supply diversions (−)	375,975	375,994	376,029	376,095	376,206
return flows (+)	566	566	566	566	566
naturalized flow inflow (+)	2,590,599	2,590,599	2,590,599	2,590,599	2,590,599
regulated flow outflow (−)	2,214,737	2,214,769	2,214,831	2,214,910	2,215,087
change in storage (+)	969	966	962	957	944
other flows (+)	-1,865	-23,696	-56,442	-111,033	-220,262
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	380,546	380,546	380,546	380,546	380,546
shortage (acre-feet/year)	4,571	4,551	4,517	4,451	4,340
volume reliability (percent)	98.80%	98.80%	98.81%	98.83%	98.86%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	757,151	757,151	757,151	757,151	757,151
mean (acre-feet)	614,168	614,204	614,266	614,360	614,578
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	37.09	37.14	37.15	37.15	37.17
99%	42.05	42.06	42.10	42.18	42.19
98%	50.11	50.12	50.13	50.14	50.30
95%	59.84	59.85	59.87	59.89	59.97
90%	65.79	65.79	65.79	65.80	65.81
80%	71.84	71.84	71.85	71.86	71.87
70%	76.21	76.22	76.23	76.25	76.34
60%	79.83	79.84	79.85	79.86	79.90
50%	83.00	83.00	83.01	83.01	83.04
40%	83.91	83.91	83.91	83.91	83.91
30%	87.07	87.07	87.08	87.09	87.11
20%	91.79	91.79	91.79	91.80	91.82
10%	97.95	97.96	97.97	97.98	98.01

Table B. 13
Cypress River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	189,720	173,886	147,189	99,977	0
reservoir precipitation (+)	188,976	192,315	195,106	198,521	204,908
water supply diversions (−)	666,426	661,461	654,747	643,724	623,658
return flows (+)	312,837	306,942	298,104	283,593	256,550
naturalized flow inflow (+)	1,748,189	1,748,189	1,748,189	1,748,189	1,748,189
regulated flow outflow (−)	1,396,388	1,414,347	1,441,259	1,487,409	1,584,216
change in storage (+)	2,550	2,306	1,955	1,529	1,127
other flows (+)	-16	-59	-157	-722	-2,899
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,162,055	1,131,278	1,085,922	1,017,248	902,898
shortage (acre-feet/year)	495,629	469,816	431,175	373,524	279,240
volume reliability (percent)	57.35%	58.47%	60.29%	63.28%	69.07%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	878,904	878,904	878,904	878,904	878,904
mean (acre-feet)	674,058	686,249	701,300	722,750	769,070
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	27.85	30.55	34.78	41.61	54.29
99%	30.89	33.76	37.90	43.88	55.33
98%	33.66	36.18	39.83	45.60	56.59
95%	41.52	44.26	48.18	53.53	65.50
90%	51.17	53.35	56.33	60.94	71.54
80%	62.86	64.69	67.32	70.82	78.37
70%	69.90	71.65	73.71	76.44	83.01
60%	75.36	76.82	78.68	81.52	87.47
50%	80.18	81.18	82.75	85.13	90.35
40%	84.21	85.51	96.93	89.19	93.71
30%	88.91	90.16	91.15	92.64	95.84
20%	93.05	93.84	94.67	95.74	97.52
10%	96.20	96.71	97.25	97.69	98.98

Table B. 14
Cypress River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	189,720	171,650	127,583	96,487	0
reservoir precipitation (+)	188,976	189,984	170,042	192,224	194,418
water supply diversions (−)	666,426	666,074	665,564	664,757	663,746
return flows (+)	312,837	311,979	310,719	308,713	305,290
naturalized flow inflow (+)	1,748,189	1,748,189	1,748,189	1,748,189	1,748,189
regulated flow outflow (−)	1,396,388	1,398,039	1,397,052	1,403,617	1,409,499
change in storage (+)	2,550	2,510	2,561	2,352	2,121
other flows (+)	-16	-16,899	-41,311	-86,617	-176,773
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,162,055	1,156,512	1,148,192	1,134,374	1,110,115
shortage (acre-feet/year)	495,629	490,439	482,628	469,617	446,369
volume reliability (percent)	57.35%	57.59%	57.97%	58.60%	59.79%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	878,904	878,904	878,903	878,904	878,904
mean (acre-feet)	674,058	677,907	671,266	688,665	700,395
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	27.85	28.93	29.92	33.29	38.64
99%	30.89	32.05	32.71	35.90	40.19
98%	33.66	34.39	34.50	38.54	42.55
95%	41.52	42.67	42.40	45.34	48.32
90%	51.17	51.86	51.70	54.87	56.74
80%	62.86	63.24	62.48	64.38	66.33
70%	69.90	70.41	69.56	71.55	72.15
60%	75.36	75.79	75.11	76.84	78.21
50%	80.18	80.49	79.76	81.32	82.38
40%	84.21	84.60	83.87	85.64	86.96
30%	88.91	89.34	88.24	90.43	91.47
20%	93.05	93.43	92.59	94.16	94.66
10%	96.20	96.52	95.21	96.89	97.50

Table B. 15
Cypress River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	189,720	170,915	142,658	956,365	0
reservoir precipitation (+)	188,976	189,152	189,445	189,949	191,137
water supply diversions (−)	666,426	666,662	666,971	667,494	668,667
return flows (+)	312,837	312,744	312,603	312,351	311,951
naturalized flow inflow (+)	1,748,189	1,748,189	1,748,189	1,748,189	1,748,189
regulated flow outflow (−)	1,396,388	1,396,566	1,396,920	1,397,569	1,399,044
change in storage (+)	2,550	2,531	2,502	2,470	2,405
other flows (+)	-16	-18,472	-46,190	768,469	-185,971
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,162,055	1,161,651	1,161,035	1,159,963	1,158,037
shortage (acre-feet/year)	495,629	494,988	494,064	492,469	489,370
volume reliability (percent)	57.35%	57.39%	57.45%	57.54%	57.74%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	878,904	878,904	878,904	878,904	878,904
mean (acre-feet)	674,058	674,750	675,941	678,068	683,508
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	27.85	28.04	28.35	28.90	30.16
99%	30.89	31.13	31.51	32.16	33.32
98%	33.66	33.77	33.95	34.24	35.08
95%	41.52	41.72	42.03	42.57	43.51
90%	51.17	51.19	51.34	51.64	52.42
80%	62.86	62.92	63.01	63.29	63.94
70%	69.90	70.04	70.28	70.41	70.77
60%	75.36	75.50	75.58	75.99	76.58
50%	80.18	80.23	80.31	80.45	80.71
40%	84.21	84.30	84.39	84.67	85.56
30%	88.91	88.97	89.09	89.54	90.34
20%	93.05	93.09	93.25	93.42	93.83
10%	96.20	96.26	96.29	96.43	96.93

Table B. 16
Cypress River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	189,720	170,795	142,383	94,993	0
reservoir precipitation (+)	188,976	189,025	189,092	189,229	189,515
water supply diversions (−)	666,426	666,578	666,810	667,179	667,899
return flows (+)	312,837	312,837	312,837	312,837	312,837
naturalized flow inflow (+)	1,748,189	1,748,189	1,748,189	1,748,189	1,748,189
regulated flow outflow (−)	1,396,388	1,396,413	1,396,451	1,396,558	1,396,849
change in storage (+)	2,550	2,640	2,548	2,546	2,546
other flows (+)	-16	-18,904	-47,021	-94,070	-188,339
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,162,055	1,162,039	1,162,014	1,161,957	1,161,792
shortage (acre-feet/year)	495,629	495,461	495,204	494,778	493,893
volume reliability (percent)	57.35%	57.36%	57.38%	57.42%	57.49%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	878,904	878,904	878,904	878,904	878,904
mean (acre-feet)	674,058	674,213	674,449	674,923	675,986
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	27.85	27.89	27.95	28.07	28.33
99%	30.89	30.93	30.99	31.10	31.34
98%	33.66	33.67	33.69	33.72	33.77
95%	41.52	41.59	41.70	41.89	42.26
90%	51.17	51.17	51.18	51.27	51.37
80%	62.86	62.88	62.89	62.98	63.16
70%	69.90	69.91	69.94	69.98	70.07
60%	75.36	75.38	75.41	75.46	75.70
50%	80.18	80.20	80.22	80.27	80.36
40%	84.21	84.23	84.26	84.30	84.33
30%	88.91	88.92	88.93	89.00	89.29
20%	93.05	93.06	93.08	93.17	93.30
10%	96.20	96.21	96.23	96.26	96.35

Table B. 17
Colorado River Basin and Brazos-Colorado Coastal Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	371,403	344,525	296,786	218,758	0
reservoir precipitation (+)	203,241	207,736	213,231	228,787	288,614
water supply diversions (−)	74,987,824	75,462,360	76,037,952	77,543,240	80,306,784
return flows (+)	73,274,992	73,737,960	74,308,976	75,780,624	78,484,752
naturalized flow inflow (+)	3,498,237	3,498,237	3,498,237	3,498,237	3,498,237
regulated flow outflow (−)	1,081,439	1,100,158	1,141,980	1,192,922	1,380,772
change in storage (+)	35,276	34,441	32,892	29,723	16,296
other flows (+)	-571,079	-571,331	-576,617	-582,451	-600,344
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	405,418,880	405,874,624	406,407,904	407,812,000	410,331,680
shortage (acre-feet/year)	330,431,136	330,412,192	330,369,888	330,268,768	330,024,864
volume reliability (percent)	18.50%	18.59%	18.71%	19.01%	19.57%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	5,200,458	5,243,391	5,254,879	5,348,528	5,100,120
mean (acre-feet)	3,019,175	3,045,799	3,073,421	3,216,360	4,132,299
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	28.13	29.14	25.02	30.16	52.10
99%	33.09	32.57	31.06	35.12	60.59
98%	34.13	34.73	33.34	38.77	64.66
95%	36.96	37.11	38.33	42.53	67.74
90%	42.54	41.91	42.22	46.17	71.34
80%	47.80	47.09	48.28	50.41	75.00
70%	52.01	51.55	52.30	54.13	77.82
60%	55.34	54.80	55.26	57.03	79.88
50%	58.15	57.96	57.80	58.86	81.31
40%	60.93	60.86	60.85	62.08	83.53
30%	63.79	63.80	64.10	65.68	85.16
20%	97.10	67.12	68.26	69.69	87.17
10%	72.64	74.13	76.19	75.13	90.76

Table B. 18
Colorado River Basin and Brazos-Colorado Coastal Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	371,403	339,130	290,554	203,485	0
reservoir precipitation (+)	203,241	205,306	208,998	215,913	244,366
water supply diversions (−)	74,987,824	75,117,688	75,354,128	75,719,488	76,438,560
return flows (+)	73,274,992	73,402,800	73,629,752	73,980,696	74,668,064
naturalized flow inflow (+)	3,498,237	3,498,237	3,498,237	3,498,237	3,498,237
regulated flow outflow (−)	1,081,439	1,087,147	1,090,406	1,098,784	1,131,225
change in storage (+)	35,276	34,754	33,861	31,668	28,576
other flows (+)	-571,079	-597,130	-635,759	-704,756	-869,457
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	405,418,880	405,549,056	405,773,472	406,115,904	406,784,416
shortage (acre-feet/year)	330,431,136	330,431,392	330,419,392	330,396,352	330,345,856
volume reliability (percent)	18.50%	18.52%	18.57%	18.64%	18.79%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	5,200,458	520,469	5,202,994	5,205,539	5,211,892
mean (acre-feet)	3,019,175	3,017,679	3,054,966	3,145,179	3,515,681
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	28.13	28.63	30.50	33.03	39.98
99%	33.09	34.14	33.30	36.14	44.92
98%	34.13	34.84	35.46	37.50	46.91
95%	36.96	37.45	37.78	40.00	50.24
90%	42.54	43.05	42.64	44.77	53.93
80%	47.80	48.00	47.65	49.78	58.92
70%	52.01	51.62	52.17	54.42	62.00
60%	55.34	54.72	55.39	57.22	64.44
50%	58.15	57.57	58.46	59.87	67.24
40%	60.93	60.14	61.06	62.99	70.14
30%	63.79	63.48	64.49	66.01	72.77
20%	97.10	67.00	67.90	69.57	75.32
10%	72.64	73.36	74.64	77.21	82.13

Table B. 19
Colorado River Basin and Brazos-Colorado Coastal Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	371,403	337,136	284,539	195,684	0
reservoir precipitation (+)	203,241	204,480	206,076	210,273	222,537
water supply diversions (−)	74,987,824	75,044,896	75,107,248	75,298,976	75,675,088
return flows (+)	73,274,992	73,329,368	73,389,576	73,569,816	73,920,472
naturalized flow inflow (+)	3,498,237	3,498,237	3,498,237	3,498,237	3,498,237
regulated flow outflow (−)	1,081,439	1,082,475	1,086,426	1,087,529	1,096,896
change in storage (+)	35,276	34,931	34,471	33,618	32,302
other flows (+)	-571,079	-602,509	-650,147	-729,754	-901,563
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	405,418,880	405,471,488	405,536,384	405,713,888	406,055,168
shortage (acre-feet/year)	330,431,136	330,426,858	330,429,088	330,414,816	330,380,128
volume reliability (percent)	18.50%	18.51%	18.52%	18.56%	18.64%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	5,200,458	5,200,550	5,200,691	5,200,936	5,201,438
mean (acre-feet)	3,019,175	3,031,776	3,025,517	3,062,731	3,205,272
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	28.13	28.27	29.00	30.97	35.45
99%	33.09	33.71	34.57	33.63	38.83
98%	34.13	34.47	35.00	35.84	39.83
95%	36.96	37.14	37.77	38.14	42.03
90%	42.54	42.75	43.25	43.19	46.81
80%	47.80	48.02	48.06	47.90	51.88
70%	52.01	52.30	51.77	52.42	55.20
60%	55.34	55.55	54.74	55.46	58.16
50%	58.15	58.41	57.76	58.79	61.14
40%	60.93	61.10	60.37	61.47	63.95
30%	63.79	64.01	63.56	64.64	67.13
20%	97.10	67.24	67.22	68.01	70.71
10%	72.64	72.81	73.36	74.45	77.14

Table B. 20
Colorado River Basin and Brazos-Colorado Coastal Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	371,403	335,262	280,795	189,254	0
reservoir precipitation (+)	203,241	203,652	204,311	205,772	208,730
water supply diversions (−)	74,987,824	75,000,320	75,022,464	75,049,272	75,108,632
return flows (+)	73,274,992	73,285,928	73,305,712	73,328,104	73,374,280
naturalized flow inflow (+)	3,498,237	3,498,237	3,498,237	3,498,237	3,498,237
regulated flow outflow (−)	1,081,439	1,081,544	1,081,855	1,082,488	1,083,789
change in storage (+)	35,276	35,205	35,101	34,930	34,636
other flows (+)	-571,079	-605,895	-658,247	-746,029	-923,462
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	405,418,880	405,430,336	405,449,408	405,470,112	405,513,760
shortage (acre-feet/year)	330,431,136	330,429,952	330,426,880	330,420,768	330,405,152
volume reliability (percent)	18.50%	18.50%	18.50%	18.51%	18.52%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	5,200,458	5,200,473	5,200,494	5,200,529	5,200,602
mean (acre-feet)	3,019,175	3,021,862	3,027,891	3,039,020	3,066,939
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	28.13	28.18	28.26	28.43	29.72
99%	33.09	33.23	33.42	33.89	34.96
98%	34.13	34.28	34.50	34.57	35.55
95%	36.96	37.00	37.10	37.44	38.33
90%	42.54	42.58	42.70	42.88	43.43
80%	47.80	47.81	47.95	48.12	48.70
70%	52.01	52.09	52.20	52.41	53.03
60%	55.34	55.41	55.51	55.72	56.09
50%	58.15	58.20	58.32	58.59	59.09
40%	60.93	60.94	61.08	61.27	61.87
30%	63.79	63.85	63.98	64.00	64.69
20%	97.10	67.09	67.14	67.61	67.64
10%	72.64	72.70	72.78	72.90	73.42

Table B. 21
Brazos River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	817,336	753,928	650,574	462,093	0
reservoir precipitation (+)	478,431	489,435	503,514	529,182	565,463
water supply diversions (−)	2,208,277	2,214,804	2,224,476	2,238,688	2,264,772
return flows (+)	100,030	100,557	101,153	102,218	105,145
naturalized flow inflow (+)	7,269,867	7,269,867	7,269,867	7,269,867	7,269,867
regulated flow outflow (−)	5,435,363	5,486,653	5,567,315	5,713,992	6,045,835
change in storage (+)	15,021	13,514	11,339	9,201	5,326
other flows (+)	597,628	582,011	556,493	504,305	364,806
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,452,861	2,451,833	2,450,384	2,448,813	2,448,133
shortage (acre-feet/year)	244,584	237,029	225,908	210,125	183,360
volume reliability (percent)	90.03%	90.33%	90.78%	91.42%	92.51%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,646,891	4,654,322	4,664,142	4,676,342	4,689,342
mean (acre-feet)	3,524,674	3,595,130	3,708,590	3,932,503	4,302,629
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	33.45	36.85	41.32	51.33	76.25
99%	37.01	40.27	45.56	55.17	78.35
98%	39.95	43.10	48.20	57.16	78.90
95%	49.11	51.65	55.89	63.74	82.80
90%	58.29	60.68	64.61	71.58	85.40
80%	67.27	69.03	72.04	78.24	88.53
70%	71.84	73.54	76.16	81.86	90.38
60%	75.55	76.85	79.45	84.29	91.75
50%	77.82	79.38	81.52	85.97	92.63
40%	80.49	81.58	83.64	87.75	93.53
30%	83.06	84.20	85.70	89.20	94.30
20%	85.56	86.46	87.98	91.24	95.33
10%	90.07	90.69	91.64	93.53	96.30

Table B. 22
Brazos River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	817,336	744,036	630,665	433,547	0
reservoir precipitation (+)	478,431	483,359	490,125	502,337	524,708
water supply diversions (−)	2,208,277	2,211,738	2,216,892	2,224,495	2,237,638
return flows (+)	100,030	100,067	100,114	100,170	100,289
naturalized flow inflow (+)	7,269,867	7,269,867	7,269,867	7,269,867	7,269,867
regulated flow outflow (−)	5,435,363	5,440,627	5,448,645	5,463,603	5,498,098
change in storage (+)	15,021	14,370	13,432	11,858	9,462
other flows (+)	597,628	528,739	422,664	237,413	-168,589
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,452,861	2,452,138	2,451,034	2,449,089	2,447,136
shortage (acre-feet/year)	244,584	240,400	234,143	224,594	209,498
volume reliability (percent)	90.03%	90.20%	90.45%	90.83%	91.44%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,646,891	4,647,617	4,648,554	4,650,075	4,652,780
mean (acre-feet)	3,524,674	3,553,388	3,599,288	3,687,056	3,888,833
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	33.45	35.07	37.75	42.52	55.17
99%	37.01	38.46	40.90	45.57	58.64
98%	39.95	41.31	43.58	47.66	60.11
95%	49.11	50.36	52.50	55.80	65.01
90%	58.29	59.41	60.88	63.54	71.12
80%	67.27	67.91	68.83	71.09	76.42
70%	71.84	72.51	73.55	75.39	80.10
60%	75.55	76.11	77.17	79.17	82.96
50%	77.82	78.51	79.43	81.29	85.22
40%	80.49	80.97	81.80	83.73	87.28
30%	83.06	83.69	84.49	85.93	89.23
20%	85.56	85.99	86.89	88.49	91.31
10%	90.07	90.30	90.76	91.86	93.61

Table B. 23
Brazos River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	817,336	739,984	621,596	420,840	0
reservoir precipitation (+)	478,431	481,063	484,166	490,189	502,028
water supply diversions (−)	2,208,277	2,210,585	2,214,169	2,220,226	2,231,850
return flows (+)	100,030	100,045	100,064	100,109	100,161
naturalized flow inflow (+)	7,269,867	7,269,867	7,269,867	7,269,867	7,269,867
regulated flow outflow (−)	5,435,363	5,436,626	5,438,432	5,442,213	5,451,608
change in storage (+)	15,021	14,679	14,198	13,282	11,340
other flows (+)	597,628	521,543	405,902	209,833	-199,938
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,452,861	2,452,348	2,451,648	2,450,423	2,448,726
shortage (acre-feet/year)	244,584	241,763	237,479	230,196	216,875
volume reliability (percent)	90.03%	90.14%	90.31%	90.61%	91.14%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,646,891	4,646,975	4,647,086	4,647,213	4,647,466
mean (acre-feet)	3,524,674	3,537,928	3,556,299	3,594,158	3,687,987
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	33.45	34.05	34.96	36.65	41.21
99%	37.01	37.53	38.33	40.02	45.32
98%	39.95	40.46	41.21	42.60	48.08
95%	49.11	49.67	50.56	52.07	55.58
90%	58.29	58.74	59.48	60.72	63.52
80%	67.27	67.53	67.75	68.35	70.24
70%	71.84	72.05	72.53	73.32	75.62
60%	75.55	75.80	76.19	77.02	79.30
50%	77.82	78.15	78.59	79.47	81.47
40%	80.49	80.75	81.09	81.95	83.91
30%	83.06	83.42	83.74	84.42	86.11
20%	85.56	85.76	86.10	86.92	88.41
10%	90.07	90.23	90.42	90.80	92.02

Table B. 24
Brazos River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	817,336	736,764	615,532	412,290	0
reservoir precipitation (+)	478,431	479,106	480,054	481,863	485,224
water supply diversions (−)	2,208,277	2,209,487	2,211,436	2,214,774	2,221,530
return flows (+)	100,030	100,046	100,065	100,104	100,146
naturalized flow inflow (+)	7,269,867	7,269,867	7,269,867	7,269,867	7,269,867
regulated flow outflow (−)	5,435,363	5,435,562	5,435,724	5,436,186	5,438,022
change in storage (+)	15,021	14,916	14,760	14,478	12,817
other flows (+)	597,628	517,878	397,946	196,937	-208,502
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,452,861	2,452,607	2,452,221	2,451,674	2,450,824
shortage (acre-feet/year)	244,584	243,120	240,785	236,900	229,295
volume reliability (percent)	90.03%	90.09%	90.18%	90.34%	90.64%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,646,891	4,646,908	4,646,930	4,646,968	4,647,039
mean (acre-feet)	3,524,674	3,527,546	3,531,953	3,541,009	3,561,845
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	33.45	33.56	33.69	33.96	34.22
99%	37.01	37.09	37.17	37.37	37.81
98%	39.95	40.02	40.09	40.25	40.39
95%	49.11	49.19	49.32	49.72	50.34
90%	58.29	58.37	58.52	58.90	59.53
80%	67.27	67.35	67.41	67.50	67.56
70%	71.84	71.96	72.00	72.22	72.68
60%	75.55	75.62	75.70	75.89	76.35
50%	77.82	77.97	78.07	78.28	78.84
40%	80.49	80.56	80.67	80.80	81.32
30%	83.06	83.18	83.36	83.57	83.77
20%	85.56	85.62	85.70	85.91	86.39
10%	90.07	90.10	90.16	90.26	90.63

Table B. 25
Trinity River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,190,660	1,090,813	927,114	637,883	0
reservoir precipitation (+)	938,847	954,393	969,845	994,782	1,039,854
water supply diversions (−)	5,903,694	5,945,331	6,009,037	6,128,463	6,420,295
return flows (+)	2,599,868	2,627,202	2,672,193	2,757,472	2,970,097
naturalized flow inflow (+)	6,757,383	6,757,382	6,757,383	6,757,383	6,757,383
regulated flow outflow (−)	3,471,310	3,562,143	3,708,689	3,962,151	4,517,485
change in storage (+)	50,741	47,302	41,903	33,622	22,191
other flows (+)	218,825	212,008	203,515	185,239	148,255
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,152,742	8,084,266	7,977,981	7,814,570	7,558,725
shortage (acre-feet/year)	2,249,048	2,138,934	1,968,945	1,686,108	1,138,429
volume reliability (percent)	72.41%	73.54%	75.32%	78.42%	84.94%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,343,323	7,348,224	7,355,523	7,367,617	7,391,399
mean (acre-feet)	5,134,741	5,222,946	5,352,262	5,573,861	6,002,287
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	7.33	10.03	13.86	23.32	43.51
99%	10.02	12.68	17.08	28.77	50.04
98%	19.91	23.89	29.68	40.76	58.23
95%	35.43	38.66	43.18	52.50	64.64
90%	46.08	48.41	51.73	57.10	68.39
80%	57.04	58.32	60.66	65.14	74.84
70%	65.45	66.76	69.05	71.88	77.97
60%	70.14	70.97	72.50	75.11	80.39
50%	74.09	75.12	76.29	78.44	82.76
40%	77.20	77.93	79.17	80.64	84.73
30%	80.55	81.15	81.92	83.51	86.40
20%	83.89	84.51	85.21	86.41	88.78
10%	88.25	88.87	89.55	90.25	91.48

Table B. 26
Trinity River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,190,660	1,076,652	903,995	609,523	0
reservoir precipitation (+)	938,847	942,891	948,781	957,897	976,031
water supply diversions (−)	5,903,694	5,932,677	5,974,719	6,044,705	6,212,990
return flows (+)	2,599,868	2,620,278	2,650,226	2,701,577	2,828,719
naturalized flow inflow (+)	6,757,383	6,757,383	6,757,383	6,757,383	6,757,383
regulated flow outflow (−)	3,471,310	3,484,420	3,504,908	3,542,356	3,605,941
change in storage (+)	50,741	49,905	48,512	45,872	40,653
other flows (+)	218,825	123,292	-21,280	-266,145	-783,856
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,152,742	8,136,903	8,108,192	8,059,528	7,943,446
shortage (acre-feet/year)	2,249,048	2,204,225	2,133,475	2,014,822	1,730,456
volume reliability (percent)	72.41%	72.91%	73.69%	75.00%	78.22%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,343,323	7,343,323	7,343,323	7,343,323	7,343,323
mean (acre-feet)	5,134,741	5,155,318	5,187,996	5,243,869	5,401,915
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	7.33	9.06	11.70	16.70	28.24
99%	10.02	11.65	14.33	20.60	34.33
98%	19.91	22.43	26.24	32.25	42.79
95%	35.43	37.21	39.16	41.50	48.90
90%	46.08	46.82	47.77	49.85	53.51
80%	57.04	57.16	57.59	58.67	62.38
70%	65.45	65.56	66.02	66.69	69.16
60%	70.14	70.15	70.34	70.67	72.43
50%	74.09	74.26	74.54	74.61	75.93
40%	77.20	77.29	77.54	77.90	79.15
30%	80.55	80.66	80.79	80.98	82.26
20%	83.89	83.94	84.02	84.01	84.65
10%	88.25	88.40	88.58	88.79	88.56

Table B. 27
Trinity River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,190,660	1,072,112	894,141	597,885	0
reservoir precipitation (+)	938,847	939,641	940,544	943,063	948,131
water supply diversions (−)	5,903,694	5,927,195	5,960,083	6,017,142	6,144,898
return flows (+)	2,599,868	2,618,766	2,645,453	2,691,357	2,796,120
naturalized flow inflow (+)	6,757,383	6,757,383	6,757,383	6,757,383	6,757,383
regulated flow outflow (−)	3,471,310	3,475,300	3,481,785	3,494,183	3,516,616
change in storage (+)	50,741	50,871	50,781	49,943	48,270
other flows (+)	218,825	107,946	-58,151	-332,536	-888,390
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,152,742	8,157,647	8,163,591	8,171,612	8,187,352
shortage (acre-feet/year)	2,249,048	2,230,452	2,203,507	2,154,470	2,042,452
volume reliability (percent)	72.41%	72.66%	73.01%	73.63%	75.05%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,343,323	7,343,323	7,343,323	7,343,323	7,343,323
mean (acre-feet)	5,134,741	5,131,451	5,126,706	5,127,114	5,154,979
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	7.33	7.96	9.04	10.75	16.49
99%	10.02	10.57	11.58	13.35	19.32
98%	19.91	20.67	21.83	24.04	28.01
95%	35.43	35.82	36.24	37.16	39.69
90%	46.08	46.05	46.16	46.34	47.40
80%	57.04	56.94	56.10	56.64	57.90
70%	65.45	65.42	65.10	64.87	65.49
60%	70.14	69.97	69.78	69.78	69.74
50%	74.09	74.03	73.92	73.74	73.74
40%	77.20	77.14	77.04	76.86	76.89
30%	80.55	80.51	80.41	80.28	80.39
20%	83.89	83.82	83.55	83.16	83.02
10%	88.25	88.18	87.92	87.77	87.54

Table B. 28
Trinity River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,190,660	1,070,047	889,484	591,482	0
reservoir precipitation (+)	938,847	938,162	936,618	935,063	933,435
water supply diversions (−)	5,903,694	5,923,547	5,951,065	5,995,044	6,092,926
return flows (+)	2,599,868	2,617,909	2,643,447	2,683,875	2,773,800
naturalized flow inflow (+)	6,757,383	6,757,383	6,757,383	6,757,383	6,757,383
regulated flow outflow (−)	3,471,310	3,473,130	3,475,804	3,480,689	3,487,507
change in storage (+)	50,741	51,143	51,372	50,969	50,336
other flows (+)	218,825	102,126	-72,466	-360,075	-934,521
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,152,742	8,167,501	8,191,481	8,224,992	8,313,562
shortage (acre-feet/year)	2,249,048	2,243,953	2,240,416	2,229,949	2,220,639
volume reliability (percent)	72.41%	72.53%	72.65%	72.89%	73.29%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,343,323	7,343,323	7,343,323	7,343,323	7,343,323
mean (acre-feet)	5,134,741	5,123,394	5,104,301	5,081,906	5,056,097
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	7.33	7.43	7.60	7.76	9.53
99%	10.02	10.14	10.20	10.46	12.15
98%	19.91	20.01	20.14	20.40	21.13
95%	35.43	35.50	35.50	35.29	35.86
90%	46.08	45.89	45.79	45.68	45.65
80%	57.04	56.81	56.52	56.26	56.08
70%	65.45	65.31	64.77	64.47	64.40
60%	70.14	69.92	69.52	69.34	68.92
50%	74.09	73.88	73.60	73.16	72.63
40%	77.20	77.05	76.83	76.35	75.58
30%	80.55	80.48	80.11	79.90	79.40
20%	83.89	83.79	83.27	82.62	81.90
10%	88.25	88.11	87.81	87.43	87.02

Table B. 29
Neches River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	648,868	591,340	501,249	342,183	0
reservoir precipitation (+)	673,660	681,275	691,785	706,912	725,638
water supply diversions (−)	1,722,814	1,719,430	1,717,819	1,714,796	1,705,652
return flows (+)	179	181	182	185	189
naturalized flow inflow (+)	6,233,344	6,233,344	6,233,344	6,233,344	3,233,344
regulated flow outflow (−)	4,605,192	4,666,705	4,763,198	4,930,714	5,280,645
change in storage (+)	21,194	19,490	17,250	12,615	4,053
other flows (+)	48,498	43,185	39,704	34,637	3,023,073
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,972,544	1,967,045	1,963,261	1,957,759	1,945,292
shortage (acre-feet/year)	249,730	247,614	245,442	242,964	239,640
volume reliability (percent)	87.34%	87.41%	87.50%	87.59%	87.68%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,904,081	3,904,094	3,904,101	3,904,101	3,904,101
mean (acre-feet)	3,390,582	3,434,763	3,508,760	3,620,757	3,763,724
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	45.33	48.86	56.94	67.75	80.53
99%	51.07	54.16	60.11	70.21	83.46
98%	54.36	57.17	62.82	72.47	85.56
95%	60.07	63.52	68.93	78.16	88.56
90%	67.73	71.08	76.04	81.58	90.19
80%	75.21	77.09	80.38	85.54	93.06
70%	82.82	84.24	86.48	90.00	95.18
60%	87.53	88.47	90.46	93.20	96.79
50%	90.48	91.40	93.14	95.72	98.19
40%	94.08	94.58	95.64	97.40	98.89
30%	96.53	97.11	97.90	98.75	99.36
20%	98.78	98.97	99.14	99.45	99.78
10%	99.40	99.50	99.70	99.95	99.99

Table B. 30
Neches River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	648,868	587,752	494,842	335,791	0
reservoir precipitation (+)	673,660	677,363	683,450	694,277	713,333
water supply diversions (−)	1,722,814	1,718,281	1,717,232	1,715,063	1,709,505
return flows (+)	179	180	180	181	183
naturalized flow inflow (+)	6,233,344	6,233,344	6,233,344	6,233,344	6,233,344
regulated flow outflow (−)	4,605,192	4,611,082	4,619,827	4,633,549	4,656,489
change in storage (+)	21,194	20,823	19,866	18,558	16,633
other flows (+)	48,498	-14,595	-104,939	-261,957	-597,498
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,972,544	1,966,404	1,963,250	1,959,179	1,951,081
shortage (acre-feet/year)	249,730	248,123	246,018	244,116	241,576
volume reliability (percent)	87.34%	87.38%	87.47%	87.54%	87.62%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,904,081	3,904,088	3,904,099	3,904,101	3,904,101
mean (acre-feet)	3,390,582	3,399,958	3,417,496	3,447,637	3,490,025
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	45.33	45.99	47.97	51.32	58.08
99%	51.07	52.55	54.90	57.80	61.72
98%	54.36	55.18	56.60	59.56	63.90
95%	60.07	61.06	62.72	65.26	68.98
90%	67.73	68.19	69.29	71.49	73.86
80%	75.21	75.56	76.36	77.32	79.43
70%	82.82	83.11	83.36	84.34	85.02
60%	87.53	87.73	87.88	88.28	88.85
50%	90.48	90.63	90.99	91.85	92.88
40%	94.08	94.12	94.46	95.04	95.10
30%	96.53	96.68	96.83	97.34	97.85
20%	98.78	98.85	98.94	99.13	99.32
10%	99.40	99.44	99.56	99.76	99.89

Table B. 31
Neches River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	648,868	584,832	488,477	327,089	0
reservoir precipitation (+)	673,660	674,383	675,534	677,870	682,878
water supply diversions (−)	1,722,814	1,717,663	1,715,983	1,714,119	1,708,944
return flows (+)	179	180	179	180	182
naturalized flow inflow (+)	6,233,344	6,233,344	6,233,344	6,233,344	6,233,344
regulated flow outflow (−)	4,605,192	4,605,938	4,606,760	4,608,323	4,612,037
change in storage (+)	21,194	21,295	21,102	20,763	20,024
other flows (+)	48,498	-20,768	-118,940	-282,626	-615,447
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,972,544	1,966,278	1,963,066	1,959,052	1,951,559
shortage (acre-feet/year)	249,730	248,615	247,082	244,933	242,614
volume reliability (percent)	87.34%	87.36%	87.41%	87.50%	87.57%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,904,081	3,904,085	3,904,092	3,904,101	3,904,101
mean (acre-feet)	3,390,582	3,391,234	3,394,531	3,401,879	3,419,934
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	45.33	45.08	45.25	45.43	47.15
99%	51.07	50.69	50.67	50.56	51.67
98%	54.36	54.07	54.32	54.58	56.04
95%	60.07	60.10	60.51	60.83	62.07
90%	67.73	67.76	68.01	68.51	69.48
80%	75.21	75.18	75.42	75.71	76.54
70%	82.82	82.83	82.93	83.06	83.58
60%	87.53	87.62	87.65	87.81	88.00
50%	90.48	90.54	90.60	90.83	91.10
40%	94.08	94.08	94.14	94.41	94.68
30%	96.53	96.62	96.67	96.87	97.14
20%	98.78	98.82	98.87	98.94	99.12
10%	99.40	99.43	99.50	99.63	99.72

Table B. 32
Neches River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	648,868	583,994	487,001	324,943	0
reservoir precipitation (+)	673,660	673,658	674,020	674,403	675,583
water supply diversions (−)	1,722,814	1,717,277	1,714,813	1,712,237	1,707,215
return flows (+)	179	180	180	179	181
naturalized flow inflow (+)	6,233,344	6,233,344	6,233,344	6,233,344	6,233,344
regulated flow outflow (−)	4,605,192	4,605,215	4,604,978	4,604,564	4,603,435
change in storage (+)	21,194	21,406	21,373	21,316	20,666
other flows (+)	48,498	-22,102	-122,125	-287,499	-619,124
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	1,972,544	1,966,417	1,963,231	1,959,442	1,952,135
shortage (acre-feet/year)	249,730	249,140	248,418	247,206	244,919
volume reliability (percent)	87.34%	87.33%	87.35%	87.38%	87.45%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,904,081	3,904,083	3,904,085	3,904,090	3,904,096
mean (acre-feet)	3,390,582	3,387,481	3,388,259	3,388,127	3,391,188
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	45.33	45.00	45.05	44.95	44.76
99%	51.07	50.32	50.28	49.81	49.30
98%	54.36	53.60	53.85	53.54	54.13
95%	60.07	59.82	59.87	59.93	60.08
90%	67.73	67.51	67.90	67.60	67.83
80%	75.21	74.96	75.07	74.86	75.12
70%	82.82	82.64	82.69	82.72	82.82
60%	87.53	87.56	87.56	87.62	87.57
50%	90.48	90.52	90.52	90.55	90.55
40%	94.08	94.02	94.07	94.14	94.22
30%	96.53	96.54	96.60	96.66	96.71
20%	98.78	98.80	98.82	98.84	98.86
10%	99.40	99.41	99.42	99.45	99.50

Table B. 33
Sabine River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,001,309	914,286	771,300	523,887	0
reservoir precipitation (+)	1,054,558	1,068,534	1,080,935	1,099,658	1,125,146
water supply diversions (−)	2,582,560	2,582,971	2,583,153	2,584,471	2,587,441
return flows (+)	330,309	330,370	330,001	330,374	331,594
naturalized flow inflow (+)	6,983,716	6,983,716	6,983,716	6,983,716	6,983,716
regulated flow outflow (−)	4,794,344	4,894,804	5,048,393	5,313,074	5,858,540
change in storage (+)	92	72	51	37	3
other flows (+)	9,539	9,368	8,143	7,647	5,521
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,613,648	2,613,619	2,613,498	2,613,452	2,613,733
shortage (acre-feet/year)	31,088	30,649	30,344	28,981	26,292
volume reliability (percent)	98.81%	98.83%	98.84%	98.89%	98.99%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	6,403,130	6,403,133	6,403,162	6,403,184	6,403,192
mean (acre-feet)	5,698,497	5,784,837	5,884,873	6,025,061	6,227,589
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	48.08	51.88	57.89	67.96	81.47
99%	51.75	55.39	62.50	70.58	85.46
98%	56.11	60.21	65.23	74.66	87.38
95%	64.45	67.62	72.84	79.44	90.08
90%	72.31	75.84	78.60	84.17	91.75
80%	80.85	82.65	85.06	88.59	94.48
70%	85.65	87.37	89.18	92.06	96.43
60%	89.40	90.89	92.41	94.59	97.97
50%	92.58	93.84	95.19	97.02	99.04
40%	95.62	96.25	97.20	98.25	99.57
30%	97.43	98.13	98.74	99.41	99.90
20%	99.13	99.40	99.70	99.92	99.99
10%	99.92	99.95	99.96	99.99	100.00

Table B. 34
Sabine River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,001,309	901,182	750,073	500,125	0
reservoir precipitation (+)	1,054,558	1,054,386	1,052,826	1,053,049	1,056,554
water supply diversions (−)	2,582,560	2,582,756	2,581,481	2,578,223	2,570,873
return flows (+)	330,309	330,275	329,837	329,740	329,756
naturalized flow inflow (+)	6,983,716	6,983,716	6,983,716	6,983,716	6,983,716
regulated flow outflow (−)	4,794,344	4,805,182	4,820,850	4,843,407	4,880,159
change in storage (+)	92	538	1,158	1,361	1,370
other flows (+)	9,539	-79,795	-215,133	-446,112	-920,364
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,613,648	2,613,582	2,614,586	2,618,198	2,626,270
shortage (acre-feet/year)	31,088	30,826	33,106	39,974	55,397
volume reliability (percent)	98.81%	98.82%	98.73%	98.47%	97.89%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	6,403,130	6,401,454	6,398,789	6,394,113	6,387,856
mean (acre-feet)	5,698,497	5,703,686	5,710,441	5,728,157	5,766,243
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	48.08	49.22	55.17	54.54	59.66
99%	51.75	52.76	55.68	60.27	65.11
98%	56.11	57.04	59.24	62.09	66.67
95%	64.45	65.25	66.09	68.45	71.13
90%	72.31	73.44	74.20	75.38	77.07
80%	80.85	80.80	81.09	81.16	82.31
70%	85.65	85.62	85.89	85.85	86.42
60%	89.40	89.29	89.30	89.45	90.10
50%	92.58	92.55	92.87	92.98	93.14
40%	95.62	95.53	95.53	95.54	95.73
30%	97.43	97.40	97.15	97.28	97.60
20%	99.13	98.96	98.52	98.46	98.65
10%	99.92	99.62	99.28	98.95	99.02

Table B. 35
Sabine River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,001,309	896,403	743,477	494,510	0
reservoir precipitation (+)	1,054,558	1,049,231	1,044,583	1,042,234	1,041,593
water supply diversions (−)	2,582,560	2,582,643	2,580,956	2,576,716	2,568,003
return flows (+)	330,309	330,308	330,284	329,947	329,724
naturalized flow inflow (+)	6,983,716	6,983,716	6,983,716	6,983,716	6,983,716
regulated flow outflow (−)	4,794,344	4,796,914	4,801,020	4,807,688	4,819,842
change in storage (+)	92	1,018	1,159	1,368	1,388
other flows (+)	9,539	-88,314	-234,289	-478,350	-968,577
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,613,648	2,613,657	2,615,460	2,619,528	2,628,452
shortage (acre-feet/year)	31,088	31,015	34,504	42,811	60,448
volume reliability (percent)	98.81%	98.81%	98.68%	98.37%	97.70%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	6,403,130	6,401,453	6,398,787	6,394,110	6,387,834
mean (acre-feet)	5,698,497	5,671,686	5,655,810	5,652,485	5,659,076
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	48.08	47.75	47.78	47.98	48.57
99%	51.75	51.42	51.35	51.52	52.02
98%	56.11	56.14	56.42	57.08	58.32
95%	64.45	64.14	64.20	64.47	64.93
90%	72.31	72.16	72.05	72.18	72.67
80%	80.85	80.32	80.04	80.09	80.46
70%	85.65	85.20	84.89	84.86	85.01
60%	89.40	88.95	88.63	88.62	88.79
50%	92.58	92.35	92.18	92.20	92.35
40%	95.62	95.18	94.95	94.98	95.02
30%	97.43	97.00	96.69	96.64	96.75
20%	99.13	98.61	98.33	98.28	98.32
10%	99.92	99.34	98.98	98.89	98.99

Table B. 36
Sabine River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,001,309	894,443	742,047	493,399	0
reservoir precipitation (+)	1,054,558	1,047,072	1,042,775	1,040,157	1,038,708
water supply diversions (−)	2,582,560	2,582,121	2,580,217	2,576,257	2,567,272
return flows (+)	330,309	330,308	330,308	330,308	330,298
naturalized flow inflow (+)	6,983,716	6,983,716	6,983,716	6,983,716	6,983,716
regulated flow outflow (−)	4,794,344	4,796,068	4,798,957	4,803,859	4,813,054
change in storage (+)	92	1,046	1,178	1,380	1,400
other flows (+)	9,539	-89,511	-236,756	-482,047	-973,796
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,613,648	2,614,106	2,616,069	2,620,128	2,629,239
shortage (acre-feet/year)	31,088	31,986	35,853	43,871	61,967
volume reliability (percent)	98.81%	98.78%	98.63%	98.33%	97.64%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	6,403,130	6,401,453	6,398,786	6,394,109	6,387,834
mean (acre-feet)	5,698,497	5,663,211	5,647,586	5,641,323	5,642,522
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	48.08	47.66	47.62	47.67	47.95
99%	51.75	51.34	51.21	51.27	51.55
98%	56.11	55.90	55.66	56.02	56.80
95%	64.45	64.02	63.88	63.97	64.36
90%	72.31	71.86	71.83	71.87	72.22
80%	80.85	80.25	80.00	80.05	80.19
70%	85.65	85.06	84.79	84.82	84.94
60%	89.40	88.70	88.55	88.61	88.74
50%	92.58	92.24	92.08	91.99	92.00
40%	95.62	95.05	94.90	94.77	94.81
30%	97.43	96.84	96.65	96.58	96.62
20%	99.13	98.47	98.27	98.20	98.28
10%	99.92	99.21	98.91	98.89	98.97

Table B. 37
Nueces River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	93,695	86,733	75,807	56,138	0
reservoir precipitation (+)	50,471	51,653	53,680	58,467	69,347
water supply diversions (−)	654,458	656,604	662,721	672,411	706,435
return flows (+)	279,358	280,462	284,642	290,212	309,772
naturalized flow inflow (+)	646,026	646,026	646,026	646,026	646,026
regulated flow outflow (−)	215,741	219,914	225,690	236,516	262,205
change in storage (+)	18,046	18,044	18,038	17,974	17,604
other flows (+)	-30,007	-32,935	-38,168	-47,613	-74,109
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	842,505	842,106	843,780	845,159	853,681
shortage (acre-feet/year)	188,047	185,502	181,060	172,749	147,246
volume reliability (percent)	77.68%	77.97%	78.54%	79.56%	82.75%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,038,516	1,038,796	1,039,000	1,039,259	1,039,592
mean (acre-feet)	273,915	281,283	295,476	326,215	409,001
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.31	0.32	0.36	0.59	2.77
99%	0.39	0.40	0.44	0.68	2.85
98%	0.40	0.42	0.47	0.76	2.87
95%	0.44	0.48	0.55	0.94	2.95
90%	0.51	0.56	0.67	1.31	3.00
80%	0.75	0.86	1.09	1.91	4.60
70%	1.35	2.26	3.38	6.25	15.23
60%	9.31	10.53	12.38	15.79	25.33
50%	17.97	18.67	21.35	24.98	35.91
40%	26.74	28.40	30.34	35.39	47.80
30%	37.78	39.54	41.49	47.22	58.92
20%	53.18	54.33	55.96	59.74	69.07
10%	69.18	69.81	70.82	74.57	82.79

Table B. 38
Nueces River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	93,695	86,184	74,808	54,017	0
reservoir precipitation (+)	50,471	51,411	53,110	56,611	64,586
water supply diversions (−)	654,458	656,745	661,868	671,946	696,977
return flows (+)	279,358	646,026	283,223	290,487	304,651
naturalized flow inflow (+)	646,026	280,243	646,026	646,026	646,026
regulated flow outflow (−)	215,741	217,831	220,701	226,556	238,383
change in storage (+)	18,046	18,044	18,039	17,991	17,718
other flows (+)	-30,007	-34,964	-43,020	-58,595	-97,622
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	842,505	842,500	843,855	847,373	854,608
shortage (acre-feet/year)	188,047	185,755	181,988	175,426	157,631
volume reliability (percent)	77.68%	77.95%	78.43%	79.30%	81.56%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,038,516	1,038,550	1,038,598	1,038,673	1,038,831
mean (acre-feet)	273,915	279,722	291,241	312,020	368,909
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.31	0.32	0.35	0.56	2.06
99%	0.39	0.40	0.43	0.64	2.10
98%	0.40	0.42	0.46	0.67	2.13
95%	0.44	0.47	0.53	0.82	2.21
90%	0.51	0.54	0.63	1.07	2.27
80%	0.75	0.82	1.02	1.60	2.86
70%	1.35	1.88	3.47	5.22	13.32
60%	9.31	10.77	12.22	14.67	22.59
50%	17.97	18.64	20.36	23.61	31.59
40%	26.74	27.90	29.91	33.54	47.77
30%	37.78	39.18	41.13	44.65	53.48
20%	53.18	53.56	55.28	57.20	63.80
10%	69.18	69.62	70.33	71.34	76.41

Table B. 39
Nueces River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	93,695	85,918	73,623	51,879	0
reservoir precipitation (+)	50,471	51,269	52,468	54,793	58,616
water supply diversions (−)	654,458	656,856	660,079	666,500	682,208
return flows (+)	279,358	279,753	281,362	284,706	294,179
naturalized flow inflow (+)	646,026	646,026	646,026	646,026	646,026
regulated flow outflow (−)	215,741	216,399	218,204	221,166	227,744
change in storage (+)	18,046	18,044	18,041	18,008	17,837
other flows (+)	-30,007	-35,920	-45,990	-63,987	-106,706
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	842,505	842,774	843,353	845,034	849,975
shortage (acre-feet/year)	188,047	185,918	183,274	178,534	167,767
volume reliability (percent)	77.68%	77.94%	78.27%	78.87%	80.26%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,038,516	1,038,525	1,038,536	1,038,548	1,038,564
mean (acre-feet)	273,915	278,812	286,281	300,128	323,589
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.31	0.32	0.34	0.50	1.39
99%	0.39	0.40	0.42	0.55	1.44
98%	0.40	0.41	0.45	0.60	1.47
95%	0.44	0.46	0.51	0.70	1.55
90%	0.51	0.53	0.57	0.86	1.61
80%	0.75	0.81	0.90	1.31	1.91
70%	1.35	2.04	3.07	4.18	7.64
60%	9.31	10.19	12.04	13.51	17.63
50%	17.97	18.73	20.01	21.82	36.34
40%	26.74	27.73	28.74	31.27	35.17
30%	37.78	38.48	39.56	41.97	44.81
20%	53.18	53.33	54.38	55.66	58.26
10%	69.18	69.42	69.89	70.40	72.30

Table B. 40
Nueces River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	93,695	84,899	71,602	48,913	0
reservoir precipitation (+)	50,471	50,732	51,190	52,131	53,657
water supply diversions (−)	654,458	655,211	656,340	658,848	664,057
return flows (+)	279,358	279,226	278,952	279,317	280,343
naturalized flow inflow (+)	646,026	646,026	646,026	646,026	646,026
regulated flow outflow (−)	215,741	215,997	216,343	217,091	218,662
change in storage (+)	18,046	18,045	18,043	18,028	17,955
other flows (+)	-30,007	-37,922	-49,926	-70,650	-115,262
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	842,505	842,383	842,112	842,273	842,695
shortage (acre-feet/year)	188,047	187,171	185,772	183,425	178,638
volume reliability (percent)	77.68%	77.78%	77.94%	78.22%	78.80%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,038,516	1,038,517	1,038,517	1,038,518	1,038,519
mean (acre-feet)	273,915	275,373	277,988	282,630	291,220
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.31	0.31	0.32	0.41	0.78
99%	0.39	0.39	0.41	0.48	0.85
98%	0.40	0.41	0.42	0.52	0.87
95%	0.44	0.45	0.48	0.58	0.92
90%	0.51	0.52	0.55	0.66	1.00
80%	0.75	0.78	0.84	0.97	1.22
70%	1.35	1.46	1.98	2.88	4.25
60%	9.31	9.60	10.09	11.16	13.07
50%	17.97	18.15	18.68	19.63	20.95
40%	26.74	26.94	27.21	28.15	29.42
30%	37.78	37.90	38.29	38.78	39.43
20%	53.18	53.20	53.31	53.71	54.43
10%	69.18	69.26	69.54	69.73	70.13

Table B. 41
Guadalupe San Antonio River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	90,653	83,477	74,874	50,247	0
reservoir precipitation (+)	53,222	54,304	55,852	58,051	60,796
water supply diversions (−)	6,418,661	6,441,948	6,480,762	6,551,866	6,704,225
return flows (+)	5,859,174	5,881,700	5,919,378	5,988,416	6,138,130
naturalized flow inflow (+)	2,120,663	2,120,663	2,120,663	2,120,663	2,120,663
regulated flow outflow (−)	1,697,338	1,702,364	1,702,364	1,726,712	1,761,663
change in storage (+)	6,811	6,568	6,104	5,574	4,759
other flows (+)	166,782	164,553	156,003	156,121	141,540
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,882,898	8,891,360	8,905,043	8,929,669	8,977,543
shortage (acre-feet/year)	2,464,235	2,449,412	2,424,283	2,377,802	2,273,316
volume reliability (percent)	72.26%	72.45%	72.78%	73.37%	74.68%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	806,659	806,676	806,688	806,725	806,725
mean (acre-feet)	585,094	594,176	607,289	628,212	660,601
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	3.09	3.91	4.93	10.46	29.47
99%	3.98	4.78	6.09	13.54	32.32
98%	4.87	6.99	10.90	21.44	39.37
95%	18.43	21.67	26.28	36.02	53.04
90%	32.78	35.39	39.22	46.84	58.87
80%	52.87	54.34	56.61	60.85	68.31
70%	65.08	66.58	68.52	71.43	75.78
60%	75.22	76.15	77.65	80.08	81.41
50%	80.90	81.73	82.82	83.99	84.48
40%	85.80	86.70	87.48	88.18	89.28
30%	91.34	91.77	92.76	93.41	94.04
20%	94.28	94.59	95.44	96.15	96.49
10%	96.85	97.29	98.31	98.74	99.12

Table B. 42
Guadalupe San Antonio River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	90,653	82,488	59,850	47,824	0
reservoir precipitation (+)	53,222	53,749	54,518	55,734	57,469
water supply diversions (−)	6,418,661	4,994,709	6,463,992	6,517,244	6,627,716
return flows (+)	5,859,174	587,571	5,903,524	5,955,612	6,064,754
naturalized flow inflow (+)	2,120,663	2,120,663	2,120,663	2,120,663	2,120,663
regulated flow outflow (−)	1,697,338	1,698,723	1,701,086	1,705,819	1,715,842
change in storage (+)	6,811	6,732	6,619	6,494	6,297
other flows (+)	166,782	4,007,206	139,604	132,383	94,375
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,882,898	7,868,416	8,900,464	8,919,855	8,957,741
shortage (acre-feet/year)	2,464,235	2,873,707	2,436,472	2,402,612	2,330,026
volume reliability (percent)	72.26%	63.48%	72.63%	73.06%	73.99%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	806,659	806,665	806,672	806,721	806,725
mean (acre-feet)	585,094	589,066	594,375	603,641	618,478
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	3.09	3.48	4.14	6.10	14.85
99%	3.98	4.37	5.06	7.36	17.33
98%	4.87	6.24	7.76	13.80	23.90
95%	18.43	19.88	22.40	27.58	36.71
90%	32.78	33.86	35.71	39.63	45.22
80%	52.87	53.30	53.50	54.43	56.65
70%	65.08	65.68	66.52	67.90	69.81
60%	75.22	75.46	75.99	77.20	78.20
50%	80.90	81.31	81.62	82.09	82.49
40%	85.80	86.31	86.64	86.99	87.35
30%	91.34	91.51	91.96	92.27	92.61
20%	94.28	94.54	95.00	95.38	95.66
10%	96.85	97.19	97.73	98.11	98.33

Table B. 43
Guadalupe San Antonio River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	90,653	802,008	68,773	46,436	0
reservoir precipitation (+)	53,222	53,476	53,780	54,384	55,270
water supply diversions (−)	6,418,661	6,435,215	6,463,001	6,514,986	6,625,407
return flows (+)	5,859,174	5,875,514	5,903,009	5,954,474	6,063,760
naturalized flow inflow (+)	2,120,663	2,120,663	2,120,663	2,120,663	2,120,663
regulated flow outflow (−)	1,697,338	1,698,575	1,700,697	1,705,003	1,713,733
change in storage (+)	6,811	6,787	6,763	6,714	6,653
other flows (+)	166,782	879,358	148,257	130,191	92,794
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,882,898	8,889,734	8,900,439	8,919,809	8,958,204
shortage (acre-feet/year)	2,464,235	2,454,519	2,437,440	2,404,823	2,332,797
volume reliability (percent)	72.26%	72.39%	72.61%	73.04%	73.96%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	806,659	806,660	80,663	806,666	806,673
mean (acre-feet)	585,094	586,756	588,123	591,516	596,823
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	3.09	3.29	3.53	3.92	5.20
99%	3.98	4.20	4.48	4.90	6.12
98%	4.87	5.26	6.28	7.22	11.93
95%	18.43	19.04	19.66	21.65	25.36
90%	32.78	33.20	33.47	34.11	36.69
80%	52.87	52.94	52.30	52.54	53.25
70%	65.08	65.46	65.73	66.28	66.58
60%	75.22	75.30	75.44	75.66	76.58
50%	80.90	81.06	81.21	81.47	81.65
40%	85.80	85.99	86.26	86.49	86.66
30%	91.34	91.45	91.50	91.62	91.80
20%	94.28	94.37	94.58	94.84	95.07
10%	96.85	97.05	97.20	97.40	97.61

Table B. 44
Guadalupe San Antonio River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	90,653	81,679	68,138	45,583	0
reservoir precipitation (+)	53,222	53,281	53,343	53,508	53,842
water supply diversions (−)	6,418,661	6,434,942	6,462,315	6,513,790	6,623,154
return flows (+)	5,859,174	5,875,422	5,902,798	5,954,096	6,063,130
naturalized flow inflow (+)	2,120,663	2,120,663	2,120,663	2,120,663	2,120,663
regulated flow outflow (−)	1,697,338	1,698,508	1,700,540	1,704,665	1,713,050
change in storage (+)	6,811	6,819	6,829	6,822	6,809
other flows (+)	166,782	158,945	147,360	128,950	91,760
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	8,882,898	8,889,701	8,900,368	8,919,709	8,957,993
shortage (acre-feet/year)	2,464,235	2,454,759	2,438,054	2,405,922	2,334,839
volume reliability (percent)	72.26%	72.39%	72.61%	73.03%	73.94%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	806,659	806,660	806,660	806,661	80,662
mean (acre-feet)	585,094	585,329	584,840	585,180	585,994
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	3.09	3.11	3.14	3.22	3.44
99%	3.98	4.01	4.06	4.17	4.45
98%	4.87	4.90	4.83	4.99	5.46
95%	18.43	18.43	17.82	17.70	17.83
90%	32.78	32.80	32.51	32.41	32.52
80%	52.87	52.89	52.21	52.24	52.02
70%	65.08	65.18	65.33	65.42	65.69
60%	75.22	75.22	75.24	75.33	75.47
50%	80.90	80.92	80.95	81.00	81.06
40%	85.80	85.83	85.86	85.93	86.03
30%	91.34	91.35	91.35	91.39	91.50
20%	94.28	94.31	94.31	94.34	94.42
10%	96.85	96.89	96.98	97.05	97.09

Table B. 45
Lavaca River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	59,317	53,838	45,184	30,399	0
reservoir precipitation (+)	47,594	48,000	48,305	48,709	49,500
water supply diversions (−)	167,098	168,054	169,518	173,316	181,081
return flows (+)	34,945	35,837	37,236	40,474	47,306
naturalized flow inflow (+)	937,025	937,025	937,025	937,025	937,025
regulated flow outflow (−)	796,441	802,167	810,085	824,487	853,989
change in storage (+)	566	528	323	210	28
other flows (+)	2,726	2,669	1,899	1,784	1,211
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	318,792	319,450	320,221	321,078	323,652
shortage (acre-feet/year)	151,694	151,396	150,703	147,763	142,571
volume reliability (percent)	52.42%	52.61%	52.94%	53.98%	55.95%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	234,778	234,778	234,778	234,778	234,778
mean (acre-feet)	207,342	208,951	211,151	213,819	218,783
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	25.62	29.40	35.14	35.93	45.24
99%	39.79	42.23	46.82	50.93	59.86
98%	48.96	51.04	55.17	59.67	67.75
95%	63.52	56.43	68.68	72.83	78.05
90%	71.67	73.00	75.02	78.08	53.23
80%	79.27	80.10	81.67	83.80	88.15
70%	84.36	85.57	86.82	88.34	91.07
60%	88.10	88.98	89.83	91.33	93.23
50%	92.07	92.62	93.23	94.53	96.02
40%	95.38	95.60	96.05	96.49	97.40
30%	99.76	99.79	99.85	99.90	99.98
20%	100.00	100.00	100.00	100.00	100.00
10%	100.00	100.00	100.00	100.00	100.00

Table B. 46
Lavaca River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	59,317	53,518	44,686	29,876	0
reservoir precipitation (+)	47,594	47,728	47,818	47,946	48,150
water supply diversions (−)	167,098	166,974	167,100	167,374	167,947
return flows (+)	34,945	35,094	35,217	35,447	35,835
naturalized flow inflow (+)	937,025	937,025	937,025	937,025	937,025
regulated flow outflow (−)	796,441	796,695	797,724	799,150	801,676
change in storage (+)	566	566	565	565	563
other flows (+)	2,726	-3,225	-11,115	-24,583	-51,950
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	318,792	318,959	319,212	319,566	319,864
shortage (acre-feet/year)	151,694	151,986	152,112	152,191	151,917
volume reliability (percent)	52.42%	52.35%	52.35%	52.38%	52.51%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	234,778	234,778	234,778	234,778	234,778
mean (acre-feet)	207,342	207,781	208,410	209,422	210,568
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	25.62	28.13	31.63	36.59	39.57
99%	39.79	40.95	42.96	46.37	51.59
98%	48.96	49.84	51.55	54.62	58.78
95%	63.52	64.24	65.40	66.82	69.10
90%	71.67	71.72	72.50	73.50	74.53
80%	79.27	79.55	79.73	80.56	81.10
70%	84.36	84.59	84.79	85.18	85.62
60%	88.10	88.17	88.29	88.71	89.17
50%	92.07	92.07	92.14	92.17	92.64
40%	95.38	95.39	95.40	95.52	95.61
30%	99.76	99.77	99.78	99.79	99.81
20%	100.00	100.00	100.00	100.00	100.00
10%	100.00	100.00	100.00	100.00	100.00

Table B. 47
Lavaca River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	59,317	53,387	44,500	29,685	0
reservoir precipitation (+)	47,594	47,600	47,613	47,642	47,687
water supply diversions (−)	167,098	166,826	166,830	166,837	166,850
return flows (+)	34,945	34,949	34,951	34,955	34,963
naturalized flow inflow (+)	937,025	937,025	937,025	937,025	937,025
regulated flow outflow (−)	796,441	796,134	796,253	796,458	796,848
change in storage (+)	566	566	566	565	564
other flows (+)	2,726	-3,792	-12,571	-27,207	-56,541
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	318,792	318,858	318,909	319,010	319,111
shortage (acre-feet/year)	151,694	152,032	152,079	152,173	152,261
volume reliability (percent)	52.42%	52.32%	52.31%	52.30%	52.29%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	234,778	234,778	234,778	234,778	234,778
mean (acre-feet)	207,342	207,403	207,444	207,613	207,908
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	25.62	26.55	27.62	29.62	33.29
99%	39.79	40.03	40.49	41.26	42.86
98%	48.96	49.07	49.23	49.51	50.18
95%	63.52	63.64	63.00	63.68	64.00
90%	71.67	71.67	71.35	71.69	72.07
80%	79.27	79.30	79.51	79.54	79.67
70%	84.36	84.45	84.45	84.46	84.52
60%	88.10	88.13	88.13	88.13	88.15
50%	92.07	92.07	92.07	92.07	92.07
40%	95.38	95.38	95.38	95.39	95.40
30%	99.76	99.76	99.77	99.77	99.78
20%	100.00	100.00	100.00	100.00	100.00
10%	100.00	100.00	100.00	100.00	100.00

Table B. 48
Lavaca River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	59,317	53,376	44,482	29,657	0
reservoir precipitation (+)	47,594	47,590	47,592	47,595	47,600
water supply diversions (−)	167,098	166,825	166,827	166,829	166,834
return flows (+)	34,945	34,948	34,949	34,950	34,952
naturalized flow inflow (+)	937,025	937,025	937,025	937,025	937,025
regulated flow outflow (−)	796,441	796,061	796,075	796,098	796,109
change in storage (+)	566	566	566	566	566
other flows (+)	2,726	-3,866	-12,748	-27,552	-57,200
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	318,792	318,808	318,858	318,858	318,858
shortage (acre-feet/year)	151,694	151,983	152,031	152,029	152,025
volume reliability (percent)	52.42%	52.33%	52.32%	52.32%	52.32%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	234,778	234,778	234,778	234,778	234,778
mean (acre-feet)	207,342	207,337	207,341	207,347	207,353
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	25.62	25.70	25.71	25.73	25.75
99%	39.79	39.74	39.74	39.75	39.76
98%	48.96	48.96	48.96	48.97	48.98
95%	63.52	63.53	63.54	63.56	63.57
90%	71.67	71.67	71.67	71.67	71.67
80%	79.27	79.30	79.30	79.30	79.30
70%	84.36	84.36	84.36	84.36	84.36
60%	88.10	88.10	88.10	88.10	88.11
50%	92.07	92.07	92.07	92.07	92.07
40%	95.38	95.38	95.38	95.38	95.38
30%	99.76	99.76	99.76	99.76	99.77
20%	100.00	100.00	100.00	100.00	100.00
10%	100.00	100.00	100.00	100.00	100.00

Table B. 49
San Jacinto River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	137,886	126,480	107,674	74,116	0
reservoir precipitation (+)	135,750	138,164	140,808	145,086	149,329
water supply diversions (−)	472,438	474,691	478,090	481,183	488,626
return flows (+)	149,422	150,548	152,260	153,729	157,349
naturalized flow inflow (+)	2,269,658	2,269,658	2,269,658	2,269,658	2,269,658
regulated flow outflow (−)	1,947,186	1,959,620	1,978,986	2,014,590	2,088,283
change in storage (+)	2,250	1,989	1,598	994	149
other flows (+)	431	432	427	423	424
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	511,652	511,652	511,652	511,652	511,652
shortage (acre-feet/year)	39,214	36,961	33,562	30,469	23,026
volume reliability (percent)	92.34%	92.78%	93.44%	94.05%	95.50%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	636,622	636,806	637,083	637,120	637,149
mean (acre-feet)	528,503	541,054	557,487	586,313	617,548
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	10.06	11.96	17.94	41.66	75.08
99%	19.97	22.04	33.28	55.50	85.00
98%	28.31	32.98	42.73	64.15	87.34
95%	45.74	50.38	58.22	69.46	90.02
90%	54.16	57.56	63.90	77.07	92.53
80%	69.97	73.37	78.27	86.49	94.98
70%	79.49	82.55	85.67	90.95	96.74
60%	85.60	87.94	85.67	94.27	98.00
50%	90.43	92.21	90.49	96.72	98.73
40%	93.82	94.94	94.21	98.10	98.93
30%	96.85	97.67	96.59	98.92	98.97
20%	98.07	98.89	98.16	99.00	99.02
10%	99.05	99.07	98.96	99.02	99.02

Table B. 50
San Jacinto River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	137,886	124,980	105,146	71,234	0
reservoir precipitation (+)	135,750	136,644	137,747	139,863	142,296
water supply diversions (−)	472,438	473,221	474,658	475,590	475,827
return flows (+)	149,422	149,822	150,566	151,033	151,116
naturalized flow inflow (+)	2,269,658	2,269,658	2,269,658	2,269,658	2,269,658
regulated flow outflow (−)	1,947,186	1,948,449	1,949,957	1,953,469	1,959,332
change in storage (+)	2,250	2,197	2,118	1,987	1,847
other flows (+)	431	-11,670	-30,329	-62,247	-129,758
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	511,652	511,652	511,652	511,652	511,652
shortage (acre-feet/year)	39,214	38,431	36,995	36,062	35,825
volume reliability (percent)	92.34%	92.49%	92.77%	92.95%	93.00%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	636,622	636,622	636,622	636,622	636,622
mean (acre-feet)	528,503	533,301	539,303	552,136	568,788
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	10.06	10.85	12.20	24.69	48.42
99%	19.97	20.78	25.55	38.83	59.61
98%	28.31	31.73	36.28	48.23	64.74
95%	45.74	48.94	52.86	58.81	69.47
90%	54.16	56.07	58.94	66.33	73.85
80%	69.97	70.99	72.93	76.21	80.27
70%	79.49	80.34	80.92	82.47	84.87
60%	85.60	85.88	86.47	88.00	89.86
50%	90.43	90.98	91.23	91.67	92.78
40%	93.82	94.13	94.48	94.92	95.75
30%	96.85	97.07	97.12	97.38	97.63
20%	98.07	98.52	98.82	98.87	98.95
10%	99.05	99.08	99.08	99.09	99.10

Table B. 51
San Jacinto River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	137,886	124,402	104,131	69,773	0
reservoir precipitation (+)	135,750	136,061	136,597	137,159	138,788
water supply diversions (−)	472,438	472,890	473,593	474,872	475,364
return flows (+)	149,422	149,650	150,017	150,679	150,913
naturalized flow inflow (+)	2,269,658	2,269,658	2,269,658	2,269,658	2,269,658
regulated flow outflow (−)	1,947,186	1,947,531	1,948,023	1,948,787	1,951,148
change in storage (+)	2,250	2,249	2,249	2,248	2,248
other flows (+)	431	-12,795	-32,774	-66,312	-135,093
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	511,652	511,652	511,652	511,652	511,652
shortage (acre-feet/year)	39,214	38,762	38,059	36,780	36,288
volume reliability (percent)	92.34%	92.42%	92.56%	92.81%	92.91%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	636,622	636,622	636,622	636,622	636,622
mean (acre-feet)	528,503	530,085	532,548	535,612	544,952
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	10.06	10.28	10.70	11.33	24.55
99%	19.97	20.21	20.88	25.93	37.74
98%	28.31	30.41	32.61	35.99	47.98
95%	45.74	47.21	49.28	51.64	55.01
90%	54.16	54.78	56.05	58.27	61.01
80%	69.97	70.23	70.53	71.37	73.19
70%	79.49	79.60	79.98	80.27	81.79
60%	85.60	85.62	85.68	85.75	87.00
50%	90.43	90.54	90.66	90.68	91.22
40%	93.82	93.96	94.09	94.15	94.52
30%	96.85	96.89	96.98	97.00	97.13
20%	98.07	98.24	98.43	98.52	98.66
10%	99.05	99.06	99.08	99.08	99.08

Table B. 52
San Jacinto River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	137,886	124,147	103,539	69,092	0
reservoir precipitation (+)	135,750	135,805	135,913	136,034	136,297
water supply diversions (−)	472,438	472,523	472,662	472,915	473,554
return flows (+)	149,422	149,463	149,537	149,659	149,989
naturalized flow inflow (+)	2,269,658	2,269,658	2,269,658	2,269,658	2,269,658
regulated flow outflow (−)	1,947,186	1,947,235	1,947,312	1,947,426	1,947,655
change in storage (+)	2,250	2,250	2,250	2,249	2,249
other flows (+)	431	-13,270	-33,844	-68,168	-136,984
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	511,652	511,652	511,652	511,652	511,652
shortage (acre-feet/year)	39,214	39,127	38,990	38,737	38,098
volume reliability (percent)	92.34%	92.35%	92.38%	92.43%	92.55%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	636,622	636,622	636,622	636,622	636,622
mean (acre-feet)	528,503	528,668	529,080	529,580	530,855
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	10.06	10.08	10.19	10.24	10.44
99%	19.97	19.99	20.11	20.17	20.55
98%	28.31	28.66	29.21	30.15	32.35
95%	45.74	45.74	45.80	45.83	45.97
90%	54.16	54.18	54.22	54.53	54.62
80%	69.97	69.97	70.04	70.19	70.47
70%	79.49	79.49	79.52	79.56	79.76
60%	85.60	85.61	85.62	85.63	85.67
50%	90.43	90.43	90.45	90.53	90.66
40%	93.82	93.82	93.85	93.85	94.02
30%	96.85	96.85	96.86	96.89	96.91
20%	98.07	98.08	98.12	98.17	98.26
10%	99.05	99.05	99.05	99.06	99.07

Table B. 53
Lower Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	15,243	14,729	14,088	15,683	0
reservoir precipitation (+)	6,876	7,332	8,281	13,471	20,444
water supply diversions (−)	21,296	21,563	21,988	22,863	26,457
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	815,318	815,318	815,318	815,318	815,318
regulated flow outflow (−)	788,282	788,936	789,982	792,010	809,808
change in storage (+)	1,283	1,261	1,209	630	49
other flows (+)	1,343	1,317	1,249	1,136	454
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	46,807	46,807	46,807	46,807	46,807
shortage (acre-feet/year)	25,511	25,244	24,819	23,944	20,350
volume reliability (percent)	45.50%	46.07%	46.98%	48.84%	56.52%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	101,593	101,630	101,654	101,682	101,709
mean (acre-feet)	29,313	30,987	34,909	59,912	93,527
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	15.53	16.34	18.62	35.59	84.70
99%	16.39	17.43	19.77	38.18	85.66
98%	16.92	17.85	20.67	39.27	85.95
95%	18.18	19.54	22.58	43.71	86.68
90%	19.29	20.67	24.18	45.93	87.23
80%	21.56	22.94	26.36	50.67	88.31
70%	23.01	24.47	28.00	54.21	89.49
60%	25.03	26.36	29.75	57.02	90.96
50%	26.69	28.13	31.53	58.74	92.06
40%	28.35	29.90	33.46	60.82	93.00
30%	30.23	31.65	35.30	62.98	94.06
20%	31.88	33.47	37.72	64.90	95.49
10%	36.69	39.29	43.50	69.47	96.78

Table B. 54
Lower Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	15,243	14,428	13,378	13,766	0
reservoir precipitation (+)	6,876	7,193	7,915	11,966	16,794
water supply diversions (−)	21,296	21,437	21,660	22,075	24,322
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	815,318	815,318	815,318	815,318	815,318
regulated flow outflow (−)	788,282	788,407	788,610	788,992	789,658
change in storage (+)	1,283	1,266	1,219	744	282
other flows (+)	1,343	495	-804	-3,196	-18,414
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	46,807	46,807	46,807	46,807	46,807
shortage (acre-feet/year)	25,511	25,370	25,147	24,732	22,485
volume reliability (percent)	45.50%	45.80%	46.28%	47.16%	51.96%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	101,593	101,593	101,593	101,593	101,593
mean (acre-feet)	29,313	30,492	33,407	52,443	74,616
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	15.53	16.07	17.69	30.34	62.74
99%	16.39	17.09	18.74	32.32	63.85
98%	16.92	17.57	19.67	33.60	64.15
95%	18.18	19.22	21.55	36.84	65.41
90%	19.29	20.23	23.24	39.53	66.39
80%	21.56	22.62	25.32	43.52	67.92
70%	23.01	24.09	27.13	46.90	69.35
60%	25.03	26.03	28.79	49.50	71.28
50%	26.69	27.86	30.62	51.67	72.94
40%	28.35	29.55	32.54	53.62	74.55
30%	30.23	31.33	34.31	56.13	76.04
20%	31.88	33.23	36.43	58.42	78.24
10%	36.69	38.13	42.39	61.12	81.45

Table B. 55
Lower Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	15,243	14,277	13,008	11,970	0
reservoir precipitation (+)	6,876	7,130	7,735	10,525	12,081
water supply diversions (−)	21,296	21,374	21,496	21,719	22,776
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	815,318	815,318	815,318	815,318	815,318
regulated flow outflow (−)	788,282	788,323	788,391	788,518	788,751
change in storage (+)	1,283	1,266	1,221	913	819
other flows (+)	1,343	260	-1,380	-4,549	-16,691
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	46,807	46,807	46,807	46,807	46,807
shortage (acre-feet/year)	25,511	25,433	25,311	25,088	24,031
volume reliability (percent)	45.50%	45.66%	45.92%	46.40%	48.66%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	101,593	101,593	101,593	101,593	101,593
mean (acre-feet)	29,313	30,236	32,609	45,091	51,957
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	15.53	15.94	17.21	26.84	37.66
99%	16.39	16.93	18.36	28.58	39.23
98%	16.92	17.42	19.19	30.01	39.91
95%	18.18	19.01	21.01	32.02	41.22
90%	19.29	20.06	22.47	34.04	42.74
80%	21.56	22.46	24.83	37.48	45.08
70%	23.01	23.98	26.39	39.62	46.93
60%	25.03	25.93	28.33	41.73	48.35
50%	26.69	27.73	30.21	43.82	49.87
40%	28.35	29.36	32.04	45.64	51.45
30%	30.23	31.14	33.84	47.59	53.10
20%	31.88	33.06	35.64	49.30	55.76
10%	36.69	37.78	40.13	53.16	59.43

Table B. 56
Lower Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	15,243	14,174	12,718	9,793	0
reservoir precipitation (+)	6,876	7,087	7,592	8,720	9,067
water supply diversions (−)	21,296	21,330	21,384	21,477	21,692
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	815,318	815,318	815,318	815,318	815,318
regulated flow outflow (−)	788,282	788,304	788,339	788,397	788,521
change in storage (+)	1,283	1,267	1,223	1,117	1,069
other flows (+)	1,343	135	-1,694	-5,488	-15,241
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	46,807	46,807	46,807	46,807	46,807
shortage (acre-feet/year)	25,511	25,477	25,423	25,330	25,115
volume reliability (percent)	45.50%	45.57%	45.68%	45.88%	46.34%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	101,593	101,593	101,593	101,593	101,593
mean (acre-feet)	29,313	30,065	31,997	36,566	38,055
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	15.53	15.84	16.85	22.29	26.16
99%	16.39	16.82	18.09	23.84	26.68
98%	16.92	17.37	18.96	24.50	26.92
95%	18.18	18.84	20.48	25.52	27.80
90%	19.29	19.92	21.95	26.87	28.84
80%	21.56	22.39	24.29	29.02	30.21
70%	23.01	23.81	25.92	30.83	32.25
60%	25.03	25.85	27.94	32.66	34.09
50%	26.69	27.59	29.62	34.58	35.91
40%	28.35	29.21	31.59	36.16	37.43
30%	30.23	31.06	33.19	37.65	39.07
20%	31.88	32.62	34.99	39.60	41.09
10%	36.69	37.34	39.08	43.89	45.19

Table B. 57
Upper Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	3,755	3,581	3,293	2,968	0
reservoir precipitation (+)	1,983	2,083	2,262	2,983	3,586
water supply diversions (−)	2,030	2,040	2,056	2,082	2,215
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	342,430	342,430	342,430	343,440	342,430
regulated flow outflow (−)	339,176	339,413	339,817	340,713	343,776
change in storage (+)	92	92	93	66	55
other flows (+)	456	429	382	-727	-79
	Vater Supply Diversions, Shortages, and Reliabilit				
diversion target (ac-ft/yr)	10,103	10,103	10,103	10,103	10,103
shortage (acre-feet/year)	8,072	8,062	8,046	8,021	7,887
volume reliability (percent)	20.10%	20.20%	20.35%	20.61%	21.93%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	10,503	10,534	10,581	10,661	11,357
mean (acre-feet)	5,764	5,927	6,226	7,368	8,588
Exceedance Frequency	eservoir Storage Volume as Percentage of Maximu				
100%	33.60	35.55	40.04	51.67	72.18
99%	36.56	38.63	43.31	55.59	72.69
98%	38.40	40.41	43.88	57.23	73.08
95%	40.49	42.42	46.11	58.60	73.58
90%	43.55	45.51	49.14	60.06	73.90
80%	47.05	48.94	52.03	63.24	74.34
70%	49.46	51.14	54.20	65.99	74.58
60%	52.15	53.47	56.63	67.68	74.82
50%	54.28	55.59	58.41	69.23	75.01
40%	56.04	57.54	59.88	70.37	75.28
30%	58.04	59.46	61.86	71.99	75.48
20%	61.14	62.26	64.11	73.87	75.52
10%	65.88	66.61	67.96	76.24	75.52

Table B. 58
Upper Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	3,755	3,500	3,105	2,603	0
reservoir precipitation (+)	1,983	2,043	2,154	2,664	3,161
water supply diversions (−)	2,030	2,037	2,047	2,061	2,082
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	342,430	342,430	342,430	342,430	342,430
regulated flow outflow (−)	339,176	339,241	339,350	339,555	339,889
change in storage (+)	92	95	92	75	64
other flows (+)	456	210	-173	-950	-3,684
	Vater Supply Diversions, Shortages, and Reliabilit				
diversion target (ac-ft/yr)	10,103	10,103	10,103	10,103	10,103
shortage (acre-feet/year)	8,072	8,065	8,055	8,042	8,021
volume reliability (percent)	20.10%	20.16%	20.26%	20.40%	20.61%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	10,503	10,503	10,503	10,503	11,357
mean (acre-feet)	5,764	5,851	6,014	6,742	7,635
Exceedance Frequency	eservoir Storage Volume as Percentage of Maximu				
100%	33.60	35.01	37.77	46.74	56.94
99%	36.56	38.15	40.85	50.53	58.00
98%	38.40	39.71	41.88	51.15	58.62
95%	40.49	41.82	44.10	53.05	59.43
90%	43.55	44.72	46.65	54.94	60.44
80%	47.05	48.14	49.87	57.49	62.24
70%	49.46	50.46	52.22	59.58	63.54
60%	52.15	52.80	54.68	62.06	64.93
50%	54.28	55.22	56.81	63.59	66.61
40%	56.04	56.95	58.48	65.56	68.04
30%	58.04	59.13	60.46	67.78	69.46
20%	61.14	61.69	62.98	69.61	71.06
10%	65.88	66.31	67.04	73.03	73.32

Table B. 59
Upper Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	3,755	3,450	2,982	1,596	0
reservoir precipitation (+)	1,983	2,019	2,082	2,330	2,775
water supply diversions (−)	2,030	2,035	2,042	2,051	2,064
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	342,430	342,430	342,430	342,430	342,430
regulated flow outflow (−)	339,176	339,199	339,235	339,302	339,418
change in storage (+)	92	92	92	81	72
other flows (+)	456	143	-345	-1,891	-3,794
	Vater Supply Diversions, Shortages, and Reliabilit				
diversion target (ac-ft/yr)	10,103	10,103	10,103	10,103	10,103
shortage (acre-feet/year)	8,072	8,068	8,061	8,051	8,039
volume reliability (percent)	20.10%	20.14%	20.21%	20.30%	20.43%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	10,503	10,502	10,503	10,503	11,075
mean (acre-feet)	5,764	5,809	5,894	6,315	6,902
Exceedance Frequency	eservoir Storage Volume as Percentage of Maximu				
100%	33.60	34.30	35.89	43.08	46.64
99%	36.56	37.23	38.37	43.95	49.15
98%	38.40	39.02	39.94	45.34	50.10
95%	40.49	41.16	42.28	47.10	51.47
90%	43.55	44.15	45.13	49.52	53.39
80%	47.05	47.64	48.64	52.61	55.81
70%	49.46	50.14	51.12	55.18	57.96
60%	52.15	52.56	53.55	57.74	60.05
50%	54.28	54.81	55.76	59.54	61.78
40%	56.04	56.64	57.44	61.64	63.48
30%	58.04	58.64	59.49	63.97	65.10
20%	61.14	61.43	62.02	65.84	67.38
10%	65.88	66.20	66.47	70.21	70.63

Table B. 60
Upper Nueces Rio Grande River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	3,755	3,405	2,877	2,084	0
reservoir precipitation (+)	1,983	1,996	2,018	2,179	2,391
water supply diversions (−)	2,030	2,032	2,035	2,041	2,050
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	342,430	342,430	342,430	342,430	342,430
regulated flow outflow (−)	339,176	339,183	339,196	339,219	339,256
change in storage (+)	92	92	92	87	82
other flows (+)	456	103	-433	-1,353	-3,597
	Vater Supply Diversions, Shortages, and Reliabilit				
diversion target (ac-ft/yr)	10,103	10,103	10,503	10,103	10,103
shortage (acre-feet/year)	8,072	8,070	5,802	8,062	8,053
volume reliability (percent)	20.10%	20.12%	19.38%	20.20%	20.29%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	10,503	10,503	10,103	10,503	10,503
mean (acre-feet)	5,764	5,778	8,067	5,974	6,267
Exceedance Frequency	eservoir Storage Volume as Percentage of Maximu				
100%	33.60	33.72	34.06	36.56	40.10
99%	36.56	36.67	36.97	39.63	43.37
98%	38.40	38.52	38.82	40.88	44.39
95%	40.49	40.67	41.07	43.65	46.28
90%	43.55	43.88	44.20	45.89	48.98
80%	47.05	47.19	47.54	49.25	51.94
70%	49.46	49.67	50.03	51.70	54.69
60%	52.15	52.24	52.62	54.16	56.96
50%	54.28	54.44	54.73	56.30	59.10
40%	56.04	56.19	56.42	58.11	60.83
30%	58.04	58.19	58.38	60.15	63.00
20%	61.14	61.23	61.37	63.00	65.52
10%	65.88	66.05	66.09	67.87	70.02

Table B. 61
San Antonio Nueces River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,758	1,632	1,421	1,009	0
reservoir precipitation (+)	1,230	1,264	1,312	1,384	1,419
water supply diversions (−)	1,051	1,064	1,086	1,119	1,171
return flows (+)	391	396	402	414	440
naturalized flow inflow (+)	565,192	565,192	565,192	565,192	565,192
regulated flow outflow (−)	564,110	564,251	564,476	564,901	565,831
change in storage (+)	2	2	2	1	1
other flows (+)	104	94	76	38	-50
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	1,434	1,434	1,434	1,434	1,434
shortage (acre-feet/year)	383	370	348	315	263
volume reliability (percent)	73.31%	74.21%	75.76%	78.05%	81.67%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,462	1,466	1,470	1,473	1,484
mean (acre-feet)	1,119	1,154	1,209	1,300	1,339
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	27.49	31.06	39.05	63.32	82.41
99%	33.26	37.00	46.18	69.86	82.41
98%	42.27	45.10	52.10	71.08	82.41
95%	47.07	50.53	57.70	75.12	82.41
90%	51.84	55.64	62.60	78.39	82.41
80%	63.17	66.21	72.26	81.43	82.41
70%	68.11	71.24	76.44	83.01	84.23
60%	73.46	75.97	80.38	85.91	89.15
50%	79.06	81.51	84.56	89.37	92.43
40%	84.35	86.22	88.96	92.41	94.93
30%	89.17	90.52	92.88	95.60	95.76
20%	9302.00	93.54	94.84	96.45	95.76
10%	95.23	96.12	96.70	96.45	95.76

Table B. 62
San Antonio Nueces River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,758	1,605	1,366	938	0
reservoir precipitation (+)	1,230	1,245	1,268	1,299	1,335
water supply diversions (−)	1,051	1,056	1,065	1,082	1,114
return flows (+)	391	393	396	401	412
naturalized flow inflow (+)	565,192	565,192	565,192	565,192	565,192
regulated flow outflow (−)	564,110	564,124	564,147	564,182	564,224
change in storage (+)	2	2	2	2	2
other flows (+)	104	-47	-279	-693	-1,603
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	1,434	1,434	1,434	1,434	1,434
shortage (acre-feet/year)	383	378	369	352	320
volume reliability (percent)	73.31%	73.67%	74.27%	75.42%	77.69%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,462	1,462	1,462	1,462	1,462
mean (acre-feet)	1,119	1,135	1,162	1,199	1,232
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	27.49	29.47	34.04	48.06	57.67
99%	33.26	35.22	40.52	53.74	61.83
98%	42.27	44.44	48.64	57.56	64.38
95%	47.07	49.34	54.56	63.27	67.66
90%	51.84	54.08	58.91	66.37	70.67
80%	63.17	64.76	67.53	70.81	73.75
70%	68.11	69.27	71.64	74.55	77.20
60%	73.46	74.53	76.63	78.62	80.89
50%	79.06	79.96	81.73	83.37	85.13
40%	84.35	85.05	86.12	87.14	89.13
30%	89.17	89.93	90.64	92.00	92.99
20%	9302.00	93.37	93.37	93.97	95.63
10%	95.23	95.76	96.38	96.63	97.21

Table B. 63
San Antonio Nueces River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,758	1,593	1,341	907	0
reservoir precipitation (+)	1,230	1,237	1,247	1,262	1,277
water supply diversions (−)	1,051	1,054	1,058	1,066	1,084
return flows (+)	391	392	394	396	401
naturalized flow inflow (+)	565,192	565,192	565,192	565,192	565,192
regulated flow outflow (−)	564,110	564,115	564,123	564,136	564,152
change in storage (+)	2	2	2	2	2
other flows (+)	104	-61	-313	-744	-1,636
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	1,434	1,434	1,434	1,434	1,434
shortage (acre-feet/year)	383	380	376	368	350
volume reliability (percent)	73.31%	73.49%	73.76%	74.31%	75.60%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,462	1,462	1,462	1,462	1,462
mean (acre-feet)	1,119	1,126	1,137	1,153	1,167
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	27.49	28.77	31.64	39.32	45.13
99%	33.26	34.88	38.22	45.31	50.38
98%	42.27	43.77	45.56	49.70	51.92
95%	47.07	48.61	51.69	55.66	58.00
90%	51.84	53.24	55.91	59.19	61.68
80%	63.17	63.90	64.86	65.99	67.00
70%	68.11	68.39	68.99	70.10	71.36
60%	73.46	73.67	72.21	75.25	76.63
50%	79.06	79.67	80.08	80.60	81.34
40%	84.35	84.63	84.86	85.23	86.10
30%	89.17	89.48	89.65	90.35	90.45
20%	9302.00	93.15	93.37	93.37	93.60
10%	95.23	95.44	95.59	96.04	96.32

Table B. 64
San Antonio Nueces River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,758	1,585	1,325	888	0
reservoir precipitation (+)	1,230	1,232	1,235	1,240	1,245
water supply diversions (−)	1,051	1,052	1,054	1,057	1,064
return flows (+)	391	392	393	394	396
naturalized flow inflow (+)	565,192	565,192	565,192	565,192	565,192
regulated flow outflow (−)	564,110	564,111	564,113	564,118	564,123
change in storage (+)	2	2	2	2	2
other flows (+)	104	-68	-328	-765	-1,648
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	1,434	1,434	1,434	1,434	1,434
shortage (acre-feet/year)	383	382	380	377	370
volume reliability (percent)	73.31%	73.39%	73.52%	73.73%	74.17%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	1,462	1,462	1,462	1,462	1,462
mean (acre-feet)	1,119	1,121	1,123	1,128	1,133
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	27.49	28.16	29.46	31.72	34.70
99%	33.26	33.73	34.80	37.86	40.01
98%	42.27	42.67	43.11	43.38	44.59
95%	47.07	47.52	48.29	50.04	50.57
90%	51.84	52.10	52.70	53.73	54.24
80%	63.17	63.25	63.44	63.69	64.18
70%	68.11	68.23	68.36	68.60	68.84
60%	73.46	73.59	73.62	73.81	74.25
50%	79.06	79.20	79.29	79.46	79.74
40%	84.35	84.36	84.41	84.55	84.93
30%	89.17	89.30	89.37	89.55	89.67
20%	93.02	93.03	93.08	93.15	93.17
10%	95.23	95.24	95.30	95.40	95.56

Table B. 65
Colorado Lavaca River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	2,651	2,417	2,050	1,402	0
reservoir precipitation (+)	2,241	2,268	2,303	2,355	2,429
water supply diversions (−)	27,423	27,445	27,478	27,533	27,612
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	396,173	396,173	396,173	396,173	396,173
regulated flow outflow (−)	368,366	368,605	368,972	369,612	371,009
change in storage (+)	17	17	14	10	10
other flows (+)	8	9	9	9	9
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	54,133	54,130	54,127	54,121	54,109
shortage (acre-feet/year)	26,710	26,686	26,649	26,588	26,497
volume reliability (percent)	50.66%	50.70%	50.77%	50.87%	51.03%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,218	7,218	7,219	7,221	7,224
mean (acre-feet)	5,418	5,477	5,572	5,721	5,923
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	26.87	29.75	34.59	41.46	50.46
99%	36.93	39.33	42.11	48.43	55.49
98%	40.10	43.05	45.36	50.79	57.71
95%	46.08	47.41	50.18	55.51	61.90
90%	52.11	53.69	56.29	60.03	66.10
80%	60.36	61.42	62.96	66.33	70.77
70%	65.89	67.27	69.25	72.89	76.59
60%	71.79	72.73	75.00	77.12	81.06
50%	78.08	78.96	80.26	82.25	84.21
40%	83.25	83.75	84.28	84.94	85.80
30%	85.74	85.93	86.73	87.87	88.66
20%	89.11	89.50	90.01	90.66	91.97
10%	94.76	95.02	95.62	96.77	97.86

Table B. 66
Colorado Lavaca River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	2,651	2,394	2,006	1,349	0
reservoir precipitation (+)	2,241	2,248	2,260	2,279	2,307
water supply diversions (−)	27,423	27,432	27,445	27,469	27,516
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	396,173	396,173	396,173	396,173	396,173
regulated flow outflow (−)	368,366	368,401	368,451	368,526	368,654
change in storage (+)	17	17	16	14	11
other flows (+)	8	-212	-547	-1,122	-2,321
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	54,133	54,132	54,132	54,131	54,129
shortage (acre-feet/year)	26,710	26,701	26,687	26,662	26,613
volume reliability (percent)	50.66%	50.68%	50.70%	50.75%	50.83%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,218	7,218	7,218	7,218	7,218
mean (acre-feet)	5,418	5,435	5,461	5,503	5,570
Exceedance Frequency	servoir Storage Volume as Percentage of Maximu				
100%	26.87	27.75	29.14	31.88	33.52
99%	36.93	37.43	38.95	39.92	41.57
98%	40.10	41.13	42.35	43.99	45.75
95%	46.08	46.28	46.60	47.80	50.50
90%	52.11	52.70	53.58	54.15	54.98
80%	60.36	60.56	61.24	61.57	62.81
70%	65.89	66.26	66.92	67.60	69.07
60%	71.79	72.10	72.31	73.58	74.85
50%	78.08	78.09	78.60	78.99	80.09
40%	83.25	83.53	83.69	84.07	84.43
30%	85.74	85.79	85.96	86.35	87.50
20%	89.11	89.29	89.47	89.99	90.50
10%	94.76	94.89	95.15	95.72	96.79

Table B. 67
Colorado Lavaca River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	2,651	2,389	1,995	1,334	0
reservoir precipitation (+)	2,241	2,243	2,248	2,255	2,268
water supply diversions (−)	27,423	27,428	27,437	27,452	27,483
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	396,173	396,173	396,173	396,173	396,173
regulated flow outflow (−)	368,366	368,375	368,388	368,409	368,449
change in storage (+)	17	17	17	16	13
other flows (+)	8	-242	-619	-1,249	-2,522
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	54,133	54,133	54,132	54,132	54,131
shortage (acre-feet/year)	26,710	26,704	26,695	26,680	26,648
volume reliability (percent)	50.66%	50.67%	50.69%	50.71%	50.77%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,218	7,218	7,218	7,218	7,218
mean (acre-feet)	5,418	5,422	5,429	5,440	5,461
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	26.87	26.96	27.18	27.60	27.79
99%	36.93	36.99	37.13	37.32	37.32
98%	40.10	40.24	40.77	41.42	41.69
95%	46.08	46.09	46.11	46.14	46.22
90%	52.11	52.14	52.20	52.20	52.22
80%	60.36	60.48	60.54	60.74	60.90
70%	65.89	66.02	66.06	66.06	66.40
60%	71.79	71.83	71.89	72.09	72.19
50%	78.08	78.09	78.18	78.43	78.71
40%	83.25	83.32	83.38	83.66	83.86
30%	85.74	85.76	85.86	85.95	86.33
20%	89.11	89.18	89.39	89.57	90.25
10%	94.76	94.84	95.00	95.35	96.03

Table B. 68
Colorado Lavaca River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	2,651	2,388	1,992	1,330	0
reservoir precipitation (+)	2,241	2,242	2,245	2,248	2,255
water supply diversions (−)	27,423	27,426	27,431	27,439	27,455
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	396,173	396,173	396,173	396,173	396,173
regulated flow outflow (−)	368,366	368,371	368,379	368,392	368,419
change in storage (+)	17	17	17	17	16
other flows (+)	8	-248	-633	-1,278	-2,571
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	54,133	54,133	54,132	54,132	54,131
shortage (acre-feet/year)	26,710	26,707	26,702	26,694	26,677
volume reliability (percent)	50.66%	50.66%	50.67%	50.69%	50.72%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	7,218	7,218	7,218	7,218	7,218
mean (acre-feet)	5,418	5,420	5,424	5,429	5,439
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	26.87	26.91	27.02	27.21	27.31
99%	36.93	36.93	36.93	36.93	36.93
98%	40.10	40.14	40.23	40.43	40.58
95%	46.08	46.09	46.11	46.14	46.21
90%	52.11	52.12	52.13	52.16	52.17
80%	60.36	60.41	60.49	60.51	60.52
70%	65.89	65.98	66.06	66.06	66.18
60%	71.79	71.82	71.85	71.92	72.06
50%	78.08	78.09	78.09	78.29	78.33
40%	83.25	83.28	83.30	83.34	83.65
30%	85.74	85.76	85.85	85.84	85.95
20%	89.11	89.14	89.30	89.42	89.72
10%	94.76	94.79	94.84	95.05	95.41

Table B. 69
Trinity San Jacinto River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,424	1,315	1,110	751	0
reservoir precipitation (+)	1,499	1,541	1,561	1,583	1,617
water supply diversions (−)	12,455	12,456	12,480	12,518	12,622
return flows (+)	338	338	338	338	338
naturalized flow inflow (+)	180,902	180,902	180,902	180,902	180,902
regulated flow outflow (−)	168,892	169,032	169,233	169,575	170,255
change in storage (+)	30	19	19	19	19
other flows (+)	2	2	2	2	2
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	16,872	16,875	16,874	16,871	16,865
shortage (acre-feet/year)	4,418	4,419	4,394	4,353	4,242
volume reliability (percent)	73.82%	73.82%	73.96%	74.20%	74.84%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,853	4,855	4,857	4,860	4,867
mean (acre-feet)	2,946	3,047	3,097	3,156	3,247
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	5.22	5.48	5.97	6.44	6.70
99%	5.97	6.28	6.59	7.15	7.50
98%	7.98	8.46	9.25	9.61	10.54
95%	13.68	14.63	15.59	17.20	18.83
90%	22.04	23.39	24.72	26.36	28.87
80%	40.38	42.90	44.75	46.79	52.71
70%	52.62	57.88	61.08	63.68	68.32
60%	64.19	70.64	71.59	73.73	76.18
50%	72.74	76.23	77.46	78.08	78.15
40%	77.17	78.30	78.32	78.27	78.35
30%	78.37	78.35	78.38	78.47	78.73
20%	78.37	78.53	78.69	78.79	79.61
10%	78.52	78.88	79.24	80.34	80.61

Table B. 70
Trinity San Jacinto River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,424	1,289	1,081	726	0
reservoir precipitation (+)	1,499	1,508	1,519	1,531	1,547
water supply diversions (−)	12,455	12,459	12,466	12,477	12,494
return flows (+)	338	338	338	338	338
naturalized flow inflow (+)	180,902	180,902	180,902	180,902	180,902
regulated flow outflow (−)	168,892	168,906	168,927	168,961	169,031
change in storage (+)	30	27	24	21	20
other flows (+)	2	-120	-308	-628	-1,281
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	16,872	16,873	16,874	16,874	16,873
shortage (acre-feet/year)	4,418	4,414	4,408	4,397	4,379
volume reliability (percent)	73.82%	73.84%	73.88%	73.94%	74.05%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,853	4,853	4,853	4,853	4,853
mean (acre-feet)	2,946	2,966	2,995	3,028	3,070
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	5.22	5.26	5.32	5.26	5.30
99%	5.97	5.99	6.06	6.15	6.23
98%	7.98	8.02	8.08	8.55	8.67
95%	13.68	13.90	14.48	15.08	16.03
90%	22.04	22.67	22.92	23.86	25.04
80%	40.38	41.44	42.46	43.56	46.57
70%	52.62	53.40	55.65	57.59	59.57
60%	64.19	65.30	67.43	68.00	69.58
50%	72.74	73.17	73.31	74.22	75.34
40%	77.17	77.34	77.69	77.90	78.07
30%	78.37	78.37	78.37	78.37	78.37
20%	78.37	78.37	78.37	78.37	78.37
10%	78.52	78.52	78.54	78.65	78.67

Table B. 71
Trinity San Jacinto River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,424	1,285	1,075	720	0
reservoir precipitation (+)	1,499	1,503	1,508	1,516	1,528
water supply diversions (−)	12,455	12,458	12,462	12,471	12,480
return flows (+)	338	338	338	338	338
naturalized flow inflow (+)	180,902	180,902	180,902	180,902	180,902
regulated flow outflow (−)	168,892	168,899	168,908	168,921	168,957
change in storage (+)	30	29	27	25	24
other flows (+)	2	-130	-331	-670	-1,355
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	16,872	16,872	16,872	16,873	16,873
shortage (acre-feet/year)	4,418	4,415	4,410	4,402	4,393
volume reliability (percent)	73.82%	73.83%	73.86%	73.91%	73.97%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,853	4,853	4,853	4,853	4,853
mean (acre-feet)	2,946	2,956	2,970	2,990	3,020
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	5.22	5.22	5.22	5.18	5.18
99%	5.97	5.97	5.97	6.00	6.10
98%	7.98	8.00	8.04	8.09	8.51
95%	13.68	13.83	14.14	14.30	14.49
90%	22.04	22.45	22.61	23.00	23.88
80%	40.38	40.87	41.90	42.89	44.22
70%	52.62	53.03	53.82	55.96	57.10
60%	64.19	64.58	65.16	66.08	67.36
50%	72.74	72.84	73.08	73.26	73.61
40%	77.17	77.26	77.48	77.72	77.85
30%	78.37	78.37	78.37	78.37	78.37
20%	78.37	78.37	78.37	78.37	78.37
10%	78.52	78.52	78.52	78.52	78.52

Table B. 72
Trinity San Jacinto River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	1,424	1,283	1,070	715	0
reservoir precipitation (+)	1,499	1,501	1,502	1,506	1,511
water supply diversions (−)	12,455	12,455	12,457	12,459	12,466
return flows (+)	338	338	338	338	338
naturalized flow inflow (+)	180,902	180,902	180,902	180,902	180,902
regulated flow outflow (−)	168,892	168,895	168,900	168,908	168,920
change in storage (+)	30	29	29	29	28
other flows (+)	2	-136	-345	-693	-1,393
	ater Supply Diversions, Shortages, and Reliabili				
diversion target (ac-ft/yr)	16,872	16,872	16,872	16,872	16,872
shortage (acre-feet/year)	4,418	4,417	4,416	4,413	4,406
volume reliability (percent)	73.82%	73.82%	73.83%	73.84%	73.88%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	4,853	4,853	4,853	4,853	4,853
mean (acre-feet)	2,946	2,950	2,955	2,963	2,975
Exceedance Frequency	servoir Storage Volume as Percentage of Maxim				
100%	5.22	5.22	5.22	5.22	5.18
99%	5.97	5.97	5.97	6.00	6.10
98%	7.98	7.98	7.98	7.98	7.99
95%	13.68	13.76	13.81	13.85	14.00
90%	22.04	22.23	22.41	22.58	22.86
80%	40.38	40.71	41.18	41.76	42.85
70%	52.62	52.65	52.98	53.95	55.05
60%	64.19	64.34	64.49	64.92	65.32
50%	72.74	72.79	72.82	72.84	73.08
40%	77.17	77.22	77.27	77.34	77.54
30%	78.37	78.37	78.37	78.37	78.37
20%	78.37	78.37	78.37	78.37	78.37
10%	78.52	78.52	78.52	78.52	78.52

Table B. 73
Neches-Trinity River Basin
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	24,587	23,707	21,583	15,481	0
reservoir precipitation (+)	30,400	31,719	33,240	34,236	34,775
water supply diversions (−)	149,028	149,514	150,152	150,869	151,787
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,152,682	1,152,682	1,152,682	1,152,682	1,152,682
regulated flow outflow (−)	1,006,584	1,007,716	1,009,534	1,013,077	1,019,140
change in storage (+)	672	640	604	586	549
other flows (+)	-3,555	-4,104	-5,257	-8,076	-17,080
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	195,045	195,045	195,044	195,042	195,038
shortage (acre-feet/year)	46,018	45,531	44,898	44,173	43,251
volume reliability (percent)	76.41%	76.66%	76.98%	77.35%	77.82%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	32,074	32,085	32,100	32,125	32,176
mean (acre-feet)	21,409	22,426	23,019	23,669	24,341
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	35.22	37.51	39.32	42.51	43.40
99%	39.83	43.90	44.48	46.06	47.74
98%	43.98	46.24	47.33	48.27	49.99
95%	47.28	50.98	52.15	53.17	55.10
90%	52.09	55.82	57.13	58.06	59.93
80%	57.25	61.51	62.43	63.07	63.62
70%	59.99	63.33	64.20	65.48	66.63
60%	61.91	65.55	66.50	67.95	69.96
50%	64.58	67.55	69.57	72.62	76.93
40%	67.14	70.75	74.29	78.83	83.92
30%	72.19	76.31	80.80	85.00	86.66
20%	80.02	83.52	85.46	87.01	87.48
10%	85.52	87.04	87.30	88.15	89.68

Table B. 74
Neches-Trinity River Basin
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	24,587	23,602	21,481	15,408	0
reservoir precipitation (+)	30,400	31,590	33,094	34,083	34,582
water supply diversions (−)	149,028	149,478	150,071	150,700	151,447
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,152,682	1,152,682	1,152,682	1,152,682	1,152,682
regulated flow outflow (−)	1,006,584	1,007,128	1,008,021	1,010,016	1,012,904
change in storage (+)	672	661	624	604	566
other flows (+)	-3,555	-4,725	-6,827	-11,245	-23,478
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	195,045	195,045	195,045	195,045	195,045
shortage (acre-feet/year)	46,018	45,567	44,974	44,345	43,597
volume reliability (percent)	76.41%	76.64%	76.94%	77.26%	77.65%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	32,074	32,076	32,077	32,080	32,085
mean (acre-feet)	21,409	21,971	22,507	23,134	23,681
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	35.22	36.11	37.14	38.17	39.34
99%	39.83	41.41	41.86	43.77	439.94
98%	43.98	45.41	45.59	46.21	47.07
95%	47.28	49.26	49.82	50.46	51.91
90%	52.09	53.51	54.81	55.81	56.77
80%	57.25	58.79	59.91	60.52	61.78
70%	59.99	61.50	62.23	63.07	64.16
60%	61.91	63.67	64.81	66.61	67.75
50%	64.58	66.21	67.67	70.04	74.64
40%	67.14	69.46	72.59	77.16	82.52
30%	72.19	75.15	80.10	84.25	85.56
20%	80.02	82.62	85.05	86.46	87.15
10%	85.52	86.72	87.22	87.99	88.80

Table B. 75
Neches-Trinity River Basin
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	24,587	23,570	21,441	15,374	0
reservoir precipitation (+)	30,400	31,549	33,034	34,008	34,487
water supply diversions (−)	149,028	149,474	150,057	150,673	151,386
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,152,682	1,152,682	1,152,682	1,152,682	1,152,682
regulated flow outflow (−)	1,006,584	1,007,098	1,007,956	1,009,898	1,012,686
change in storage (+)	672	665	630	614	581
other flows (+)	-3,555	-4,755	-6,892	-11,358	-23,678
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	195,045	195,045	195,045	195,045	195,045
shortage (acre-feet/year)	46,018	45,572	44,988	44,373	43,659
volume reliability (percent)	76.41%	76.64%	76.93%	77.25%	77.62%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	32,074	32,074	32,074	32,074	32,074
mean (acre-feet)	21,409	21,839	22,301	22,874	23,358
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	35.22	35.39	35.66	36.07	36.68
99%	39.83	40.93	41.14	42.80	43.16
98%	43.98	44.67	45.11	45.62	46.31
95%	47.28	49.12	49.51	49.74	50.54
90%	52.09	53.23	53.77	54.88	55.83
80%	57.25	58.29	58.88	59.98	60.66
70%	59.99	60.90	61.36	62.49	63.22
60%	61.91	63.15	64.15	65.59	66.83
50%	64.58	66.03	67.01	69.18	73.09
40%	67.14	68.96	71.66	76.39	80.80
30%	72.19	74.93	79.47	83.72	84.92
20%	80.02	82.23	84.46	85.90	86.59
10%	85.52	86.36	86.81	87.46	88.09

Table B. 76
Neches-Trinity River Basin
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	24,587	23,520	21,395	15,340	0
reservoir precipitation (+)	30,400	31,490	32,968	33,932	34,411
water supply diversions (−)	149,028	149,465	150,037	150,630	151,295
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,152,682	1,152,682	1,152,682	1,152,682	1,152,682
regulated flow outflow (−)	1,006,584	1,007,087	1,007,927	1,009,842	1,012,574
change in storage (+)	672	670	636	621	590
other flows (+)	-3,555	-4,770	-6,927	-11,424	-23,813
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	195,045	195,045	195,045	195,045	195,045
shortage (acre-feet/year)	46,018	45,580	45,009	44,416	43,750
volume reliability (percent)	76.41%	76.63%	76.92%	77.23%	77.57%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	32,074	32,074	32,074	32,074	32,074
mean (acre-feet)	21,409	21,668	22,105	22,646	23,123
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	35.22	35.26	35.32	35.39	35.59
99%	39.83	40.05	40.29	42.46	42.55
98%	43.98	44.36	44.46	45.24	45.88
95%	47.28	48.64	48.98	49.23	49.72
90%	52.09	52.57	53.00	53.89	55.14
80%	57.25	57.66	58.29	59.24	59.88
70%	59.99	60.24	60.78	61.71	62.48
60%	61.91	62.62	63.34	64.83	65.96
50%	64.58	65.19	66.42	68.50	71.80
40%	67.14	98.46	71.25	75.42	80.24
30%	72.19	74.43	78.88	83.08	84.35
20%	80.02	81.94	83.69	85.16	85.91
10%	85.52	85.90	86.19	86.81	87.45

Table B. 77
Rio Grande Basin - Red Bluff Reservoir
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	6,186	5,639	4,792	3,305	0
reservoir precipitation (+)	1,292	1,307	1,328	1,366	1,470
water supply diversions (−)	12,880	12,964	13,032	13,084	13,407
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	124,194	124,194	124,194	124,194	124,194
regulated flow outflow (−)	112,114	112,496	113,147	114,346	116,727
change in storage (+)	4,774	4,773	4,773	4,772	4,770
other flows (+)	920	825	675	403	-301
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	66,625	66,625	66,625	66,625	66,625
shortage (acre-feet/year)	53,745	53,661	53,594	53,541	53,218
volume reliability (percent)	19.33%	19.46%	19.56%	19.64%	20.12%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	300,000	300,000	300,000	300,000	300,000
mean (acre-feet)	19,475	19,654	19,936	20,418	21,462
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.00	0.00	0.00	0.00	0.00
99%	0.00	0.00	0.00	0.00	0.00
98%	0.00	0.00	0.00	0.00	0.00
95%	0.00	0.00	0.00	0.00	0.00
90%	0.00	0.00	0.00	0.00	0.00
75%	0.00	0.00	0.00	0.00	0.00
60%	0.00	0.00	0.00	0.00	0.00
50%	0.00	0.00	0.00	0.00	0.00
40%	0.00	0.00	0.00	0.00	0.00
25%	0.01	0.01	0.01	0.01	0.01
10%	0.16	0.17	0.18	0.19	0.22

Table B. 78
Rio Grande Basin - Red Bluff Reservoir
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	6,186	5,609	4,728	3,219	0
reservoir precipitation (+)	1,292	1,300	1,311	1,333	1,388
water supply diversions (−)	12,880	12,935	13,010	13,084	13,260
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	124,194	124,194	124,194	124,194	124,194
regulated flow outflow (−)	112,114	112,290	112,572	113,123	114,311
change in storage (+)	4,774	4,773	4,773	4,772	4,770
other flows (+)	920	566	32	-873	-2,781
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	66,625	66,625	66,625	66,625	66,625
shortage (acre-feet/year)	53,745	53,690	53,615	53,541	53,365
volume reliability (percent)	19.33%	19.41%	19.53%	19.64%	19.90%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	300,000	300,000	300,000	300,000	300,000
mean (acre-feet)	19,475	19,575	19,729	20,000	20,581
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.00	0.00	0.00	0.00	0.00
99%	0.00	0.00	0.00	0.00	0.00
98%	0.00	0.00	0.00	0.00	0.00
95%	0.00	0.00	0.00	0.00	0.00
90%	0.00	0.00	0.00	0.00	0.00
75%	0.00	0.00	0.00	0.00	0.00
60%	0.00	0.00	0.00	0.00	0.00
50%	0.00	0.00	0.00	0.00	0.00
40%	0.00	0.00	0.00	0.00	0.00
25%	0.01	0.01	0.01	0.01	0.01
10%	0.16	0.16	0.17	0.19	0.10

Table B. 79
Rio Grande Basin - Red Bluff Reservoir
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	6,186	5,591	4,690	3,164	0
reservoir precipitation (+)	1,292	1,297	1,303	1,314	1,341
water supply diversions (−)	12,880	12,918	12,967	13,063	13,260
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	124,194	124,194	124,194	124,194	124,194
regulated flow outflow (−)	112,114	112,249	112,467	112,832	113,625
change in storage (+)	4,774	4,773	4,773	4,772	4,770
other flows (+)	920	494	-146	-1,221	-3,421
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	66,625	66,625	66,625	66,625	66,625
shortage (acre-feet/year)	53,745	53,707	53,658	53,562	53,365
volume reliability (percent)	19.33%	19.39%	19.46%	19.61%	19.90%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	300,000	300,000	300,000	300,000	300,000
mean (acre-feet)	19,475	19,535	19,628	19,785	20,119
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.00	0.00	0.00	0.00	0.00
99%	0.00	0.00	0.00	0.00	0.00
98%	0.00	0.00	0.00	0.00	0.00
95%	0.00	0.00	0.00	0.00	0.00
90%	0.00	0.00	0.00	0.00	0.00
75%	0.00	0.00	0.00	0.00	0.00
60%	0.00	0.00	0.00	0.00	0.00
50%	0.00	0.00	0.00	0.00	0.00
40%	0.00	0.00	0.00	0.00	0.00
25%	0.01	0.01	0.01	0.01	0.01
10%	0.16	0.16	0.16	0.17	0.18

Table B. 80
Rio Grande Basin - Red Bluff Reservoir
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	6,186	5,577	4,661	3,122	0
reservoir precipitation (+)	1,292	1,295	1,298	1,303	1,313
water supply diversions (−)	12,880	12,906	12,954	13,036	13,189
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	124,194	124,194	124,194	124,194	124,194
regulated flow outflow (−)	112,114	112,200	112,323	112,533	112,978
change in storage (+)	4,774	4,773	4,773	4,772	4,770
other flows (+)	920	421	-327	-1,578	-4,110
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	66,625	66,625	66,625	66,625	66,625
shortage (acre-feet/year)	53,745	53,719	53,671	53,589	53,436
volume reliability (percent)	19.33%	19.37%	19.44%	19.57%	19.80%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	300,000	300,000	300,000	300,000	300,000
mean (acre-feet)	19,475	19,505	19,551	19,629	19,785
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.00	0.00	0.00	0.00	0.00
99%	0.00	0.00	0.00	0.00	0.00
98%	0.00	0.00	0.00	0.00	0.00
95%	0.00	0.00	0.00	0.00	0.00
90%	0.00	0.00	0.00	0.00	0.00
75%	0.00	0.00	0.00	0.00	0.00
60%	0.00	0.00	0.00	0.00	0.00
50%	0.00	0.00	0.00	0.00	0.00
40%	0.00	0.00	0.00	0.00	0.00
25%	0.01	0.01	0.01	0.01	0.01
10%	0.16	0.16	0.16	0.17	0.18

Table B. 81
Rio Grande Basin – Amistad and Flacon Reservoirs
Evaporation Suppression Trigger = 100 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	290,993	265,688	224,473	153,622	0
reservoir precipitation (+)	83,126	84,563	85,580	87,513	91,444
water supply diversions (−)	1,406,738	1,411,585	1,419,058	1,431,984	1,457,433
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,099,597	1,099,597	1,099,597	1,099,597	1,099,597
regulated flow outflow (−)	48,999	49,970	51,285	54,021	59,975
change in storage (+)	23,793	23,791	23,788	23,783	23,738
other flows (+)	540,214	519,292	485,851	428,734	302,628
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,017,696	2,017,703	2,017,713	2,017,731	2,017,767
shortage (acre-feet/year)	610,958	606,120	598,755	58,530	560,277
volume reliability (percent)	69.72%	69.96%	70.33%	70.97%	72.23%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,224,044	3,224,044	3,224,044	3,224,044	3,224,044
mean (acre-feet)	926,143	933,326	945,233	970,485	1,027,139
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.07	0.07	0.07	0.07	0.07
99%	0.08	0.08	0.08	0.08	0.08
98%	0.09	0.09	0.09	0.09	0.09
95%	0.09	0.09	0.09	0.09	0.09
90%	0.10	0.10	0.10	0.10	0.10
75%	0.11	0.11	0.11	0.11	0.11
60%	0.13	0.13	0.13	0.13	0.14
50%	0.17	0.17	0.18	0.18	0.21
40%	0.25	0.25	0.25	0.27	0.30
25%	0.42	0.42	0.42	0.44	0.46
10%	0.67	0.67	0.68	0.70	0.73

Table B. 82
Rio Grande Basin – Amistad and Flacon Reservoirs
Evaporation Suppression Trigger = 75 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	290,993	265,091	237,730	479,250	0
reservoir precipitation (+)	83,126	88,817	106,223	423,200	146,634
water supply diversions (−)	1,406,738	1,415,616	1,428,732	1,450,725	1,498,747
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,099,597	1,099,597	1,099,597	1,099,597	1,099,597
regulated flow outflow (−)	48,999	49,329	49,877	50,920	52,866
change in storage (+)	23,793	23,791	23,786	23,780	23,774
other flows (+)	540,214	517,831	486,733	434,318	281,609
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,017,696	2,017,697	2,017,698	2,017,699	2,017,700
shortage (acre-feet/year)	610,968	602,045	588,941	566,917	518,966
volume reliability (percent)	69.72%	70.16%	70.81%	71.90%	74.28%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,224,044	3,224,044	3,224,044	3,224,044	3,224,044
mean (acre-feet)	926,143	934,795	949,002	976,215	1,042,751
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.07	0.07	0.07	0.07	0.08
99%	0.08	0.08	0.08	0.08	0.09
98%	0.09	0.09	0.09	0.09	0.09
95%	0.09	0.09	0.09	0.09	0.10
90%	0.10	0.10	0.10	0.10	0.10
75%	0.11	0.11	0.11	0.11	0.11
60%	0.13	0.13	0.13	0.14	0.15
50%	0.17	0.18	0.18	0.19	0.23
40%	0.25	0.25	0.26	0.28	0.32
25%	0.42	0.42	0.42	0.44	0.47
10%	0.67	0.67	0.68	0.70	0.73

Table B. 83
Rio Grande Basin – Amistad and Flacon Reservoirs
Evaporation Suppression Trigger = 50 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	290,993	260,392	234,801	453,443	0
reservoir precipitation (+)	83,126	85,978	105,672	399,122	157,249
water supply diversions (−)	1,406,738	1,412,791	1,431,355	1,455,568	1,501,370
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,099,597	1,099,597	1,099,597	1,099,597	1,099,597
regulated flow outflow (−)	48,999	49,110	49,300	49,876	510,808
change in storage (+)	23,793	23,790	23,787	23,783	23,761
other flows (+)	540,214	512,929	486,401	436,385	731,571
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,017,696	2,017,697	2,017,698	2,017,699	2,017,700
shortage (acre-feet/year)	610,958	601,353	586,324	562,095	516,380
volume reliability (percent)	69.72%	70.02%	70.94%	72.14%	74.41%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,224,044	3,224,044	3,224,044	3,224,044	3,224,044
mean (acre-feet)	926,143	933,087	944,973	969,885	1,022,814
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.07	0.07	0.07	0.07	0.07
99%	0.08	0.08	0.08	0.08	0.09
98%	0.09	0.09	0.09	0.09	0.09
95%	0.09	0.09	0.09	0.09	0.10
90%	0.10	0.10	0.10	0.10	0.10
75%	0.11	0.11	0.11	0.11	0.11
60%	0.13	0.13	0.13	0.14	0.15
50%	0.17	0.17	0.18	0.19	0.22
40%	0.25	0.25	0.26	0.27	0.31
25%	0.42	0.42	0.42	0.44	0.46
10%	0.67	0.67	0.68	0.69	0.71

Table B. 84
Rio Grande Basin – Amistad and Flacon Reservoirs
Evaporation Suppression Trigger = 25 Percent of Storage Capacity

evaporation reduction	0%	10%	25%	50%	100%
	Volume Budget for River Basin (acre-feet/year)				
reservoir evaporation (−)	290,993	258,993	224,490	212,991	0
reservoir precipitation (+)	83,126	85,472	94,953	158,003	151,643
water supply diversions (−)	1,406,738	1,415,616	1,427,925	1,449,717	1,484,220
return flows (+)	0	0	0	0	0
naturalized flow inflow (+)	1,099,597	1,099,597	1,099,597	1,099,597	1,099,597
regulated flow outflow (−)	48,999	48,924	506,309	48,695	48,508
change in storage (+)	23,793	23,790	23,786	23,779	23,771
other flows (+)	540,214	514,675	940,387	430,022	257,717
	Water Supply Diversions, Shortages, and Reliability				
diversion target (ac-ft/yr)	2,017,696	2,017,697	2,017,698	2,017,699	2,017,700
shortage (acre-feet/year)	610,958	602,146	589,726	568,051	533,498
volume reliability (percent)	69.72%	70.16%	70.77%	71.85%	73.56%
	Reservoir Storage Capacity (acre-feet)				
maximum (acre-feet)	3,224,044	3,224,044	3,224,044	3,224,044	3,224,044
mean (acre-feet)	926,143	930,816	937,217	948,346	975,772
Exceedance Frequency	Reservoir Storage Volume as Percentage of Maximum				
100%	0.07	0.07	0.07	0.07	0.08
99%	0.08	0.08	0.08	0.08	0.09
98%	0.09	0.09	0.09	0.09	0.09
95%	0.09	0.09	0.09	0.10	0.10
90%	0.10	0.10	0.10	0.10	0.10
75%	0.11	0.11	0.11	0.11	0.11
60%	0.13	0.13	0.13	0.13	0.14
50%	0.17	0.17	0.18	0.18	0.20
40%	0.25	0.25	0.25	0.26	0.28
25%	0.42	0.42	0.42	0.42	0.43
10%	0.67	0.67	0.67	0.67	0.69